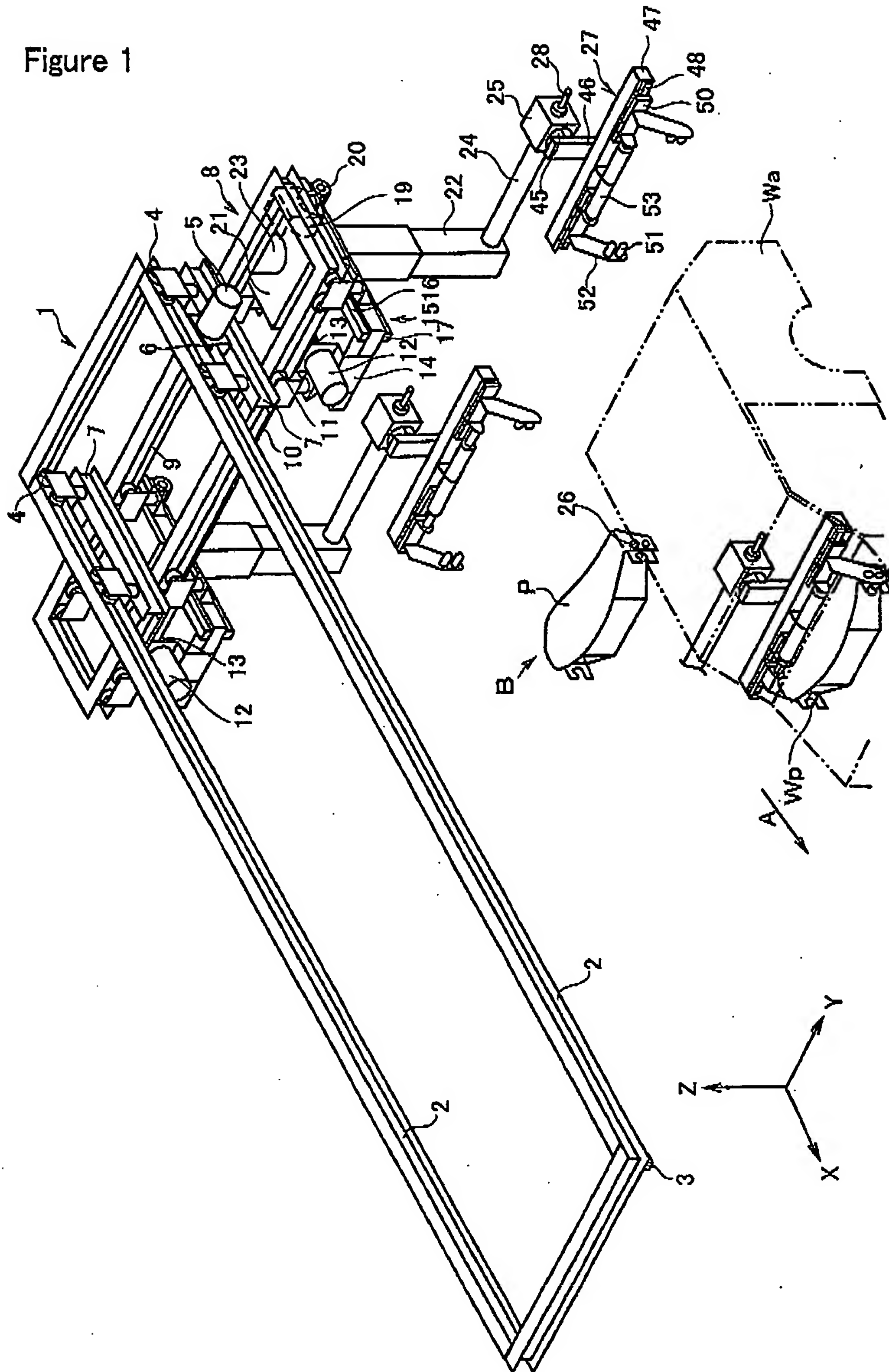


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Figure 1



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Figure 2

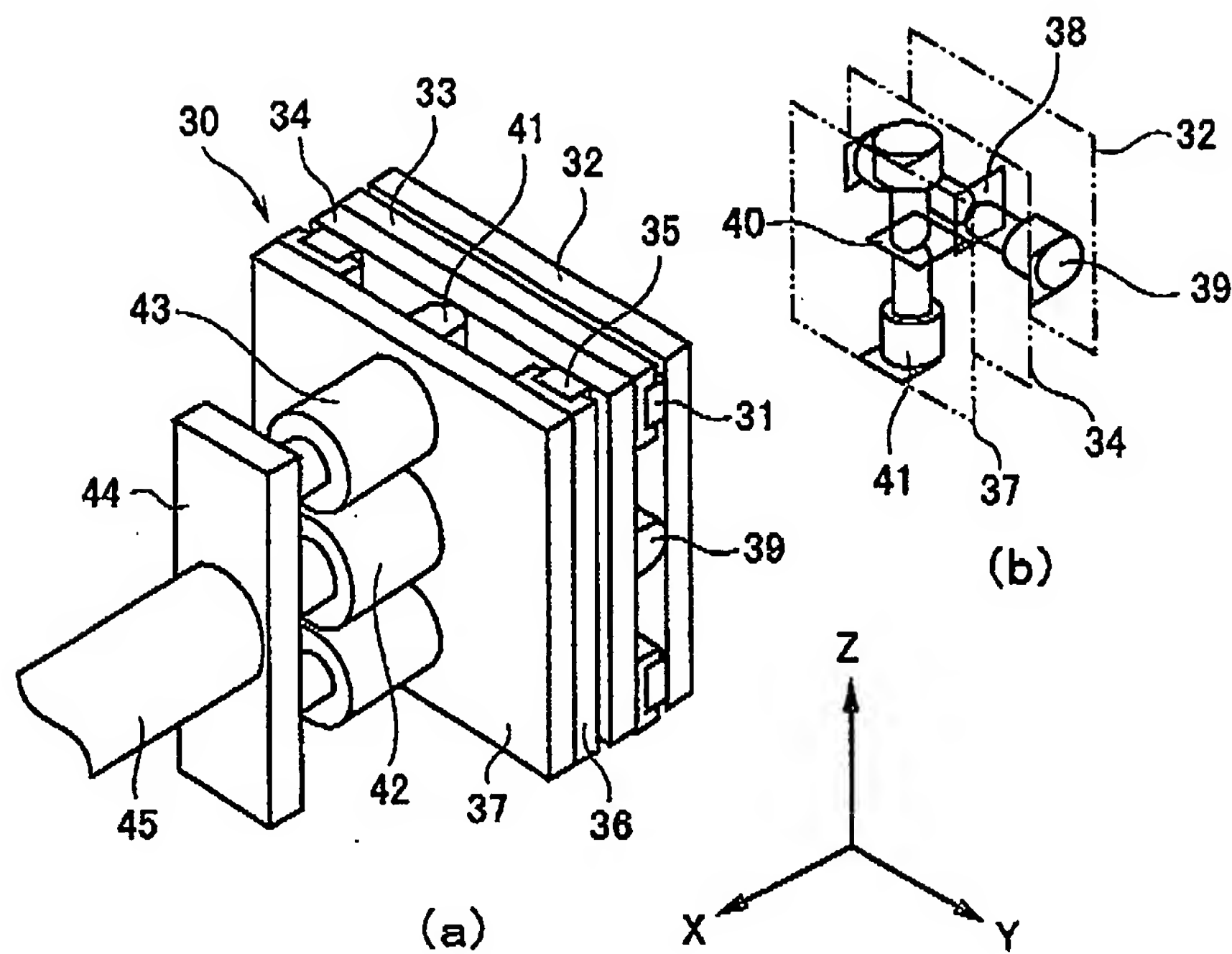
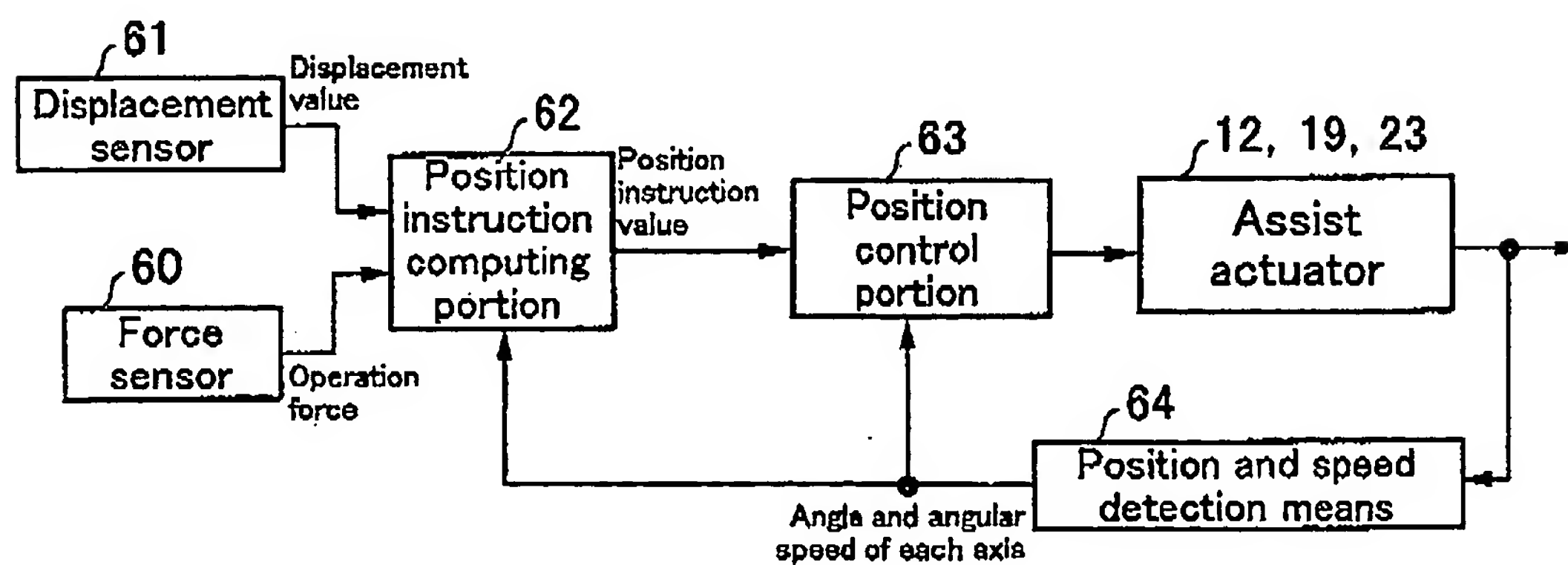


Figure 3



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Figure 4

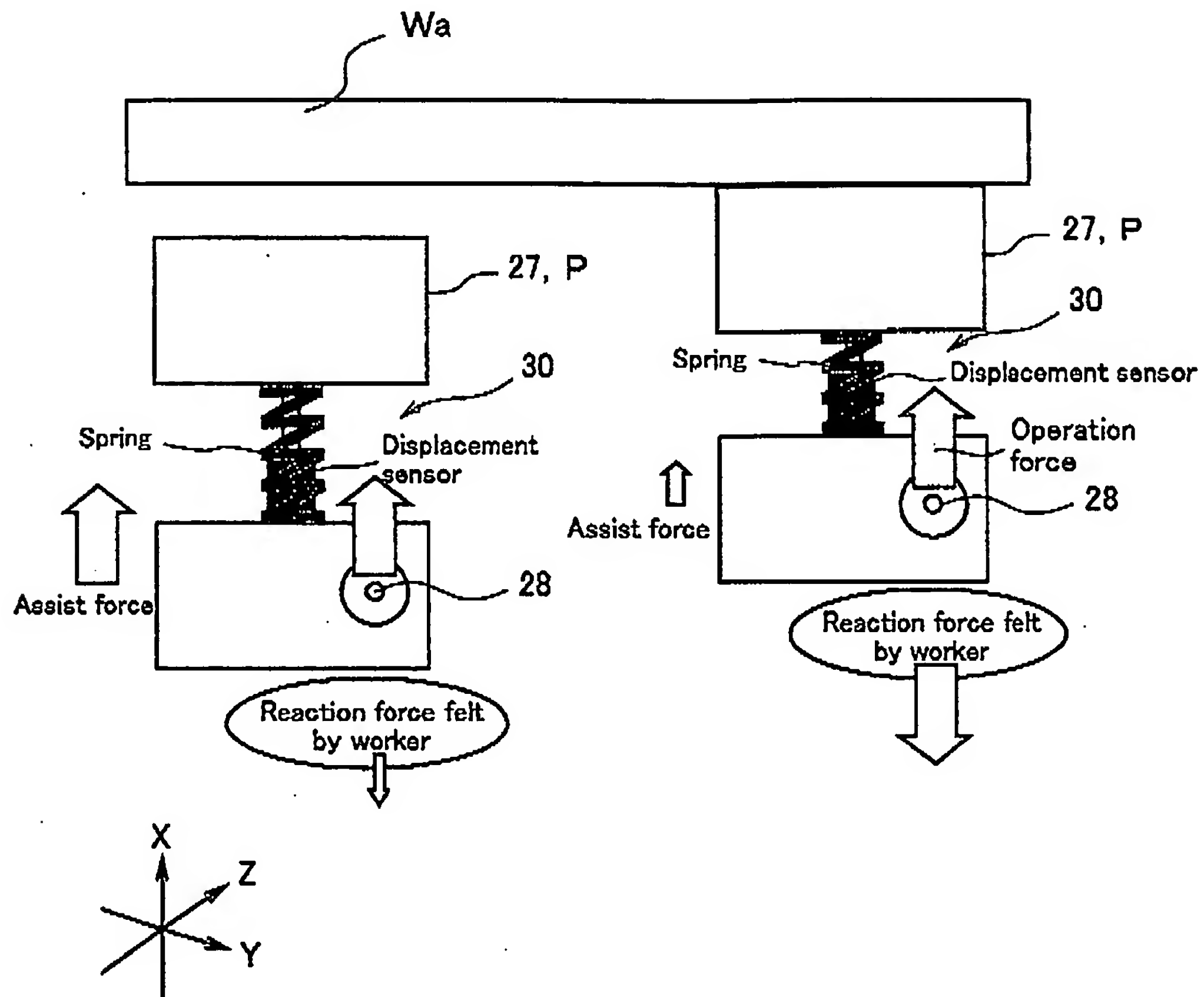
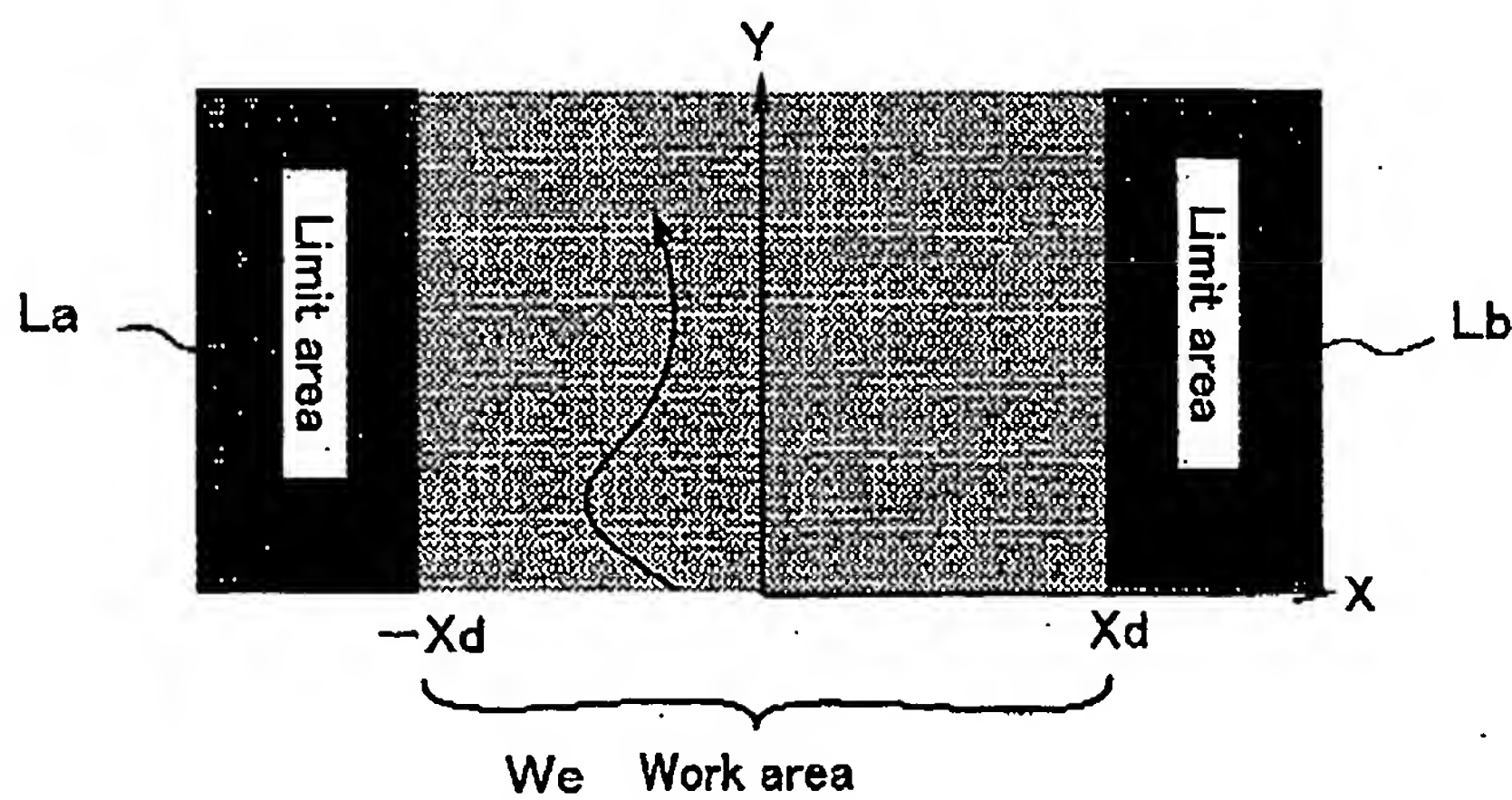


Figure 5



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Figure 6

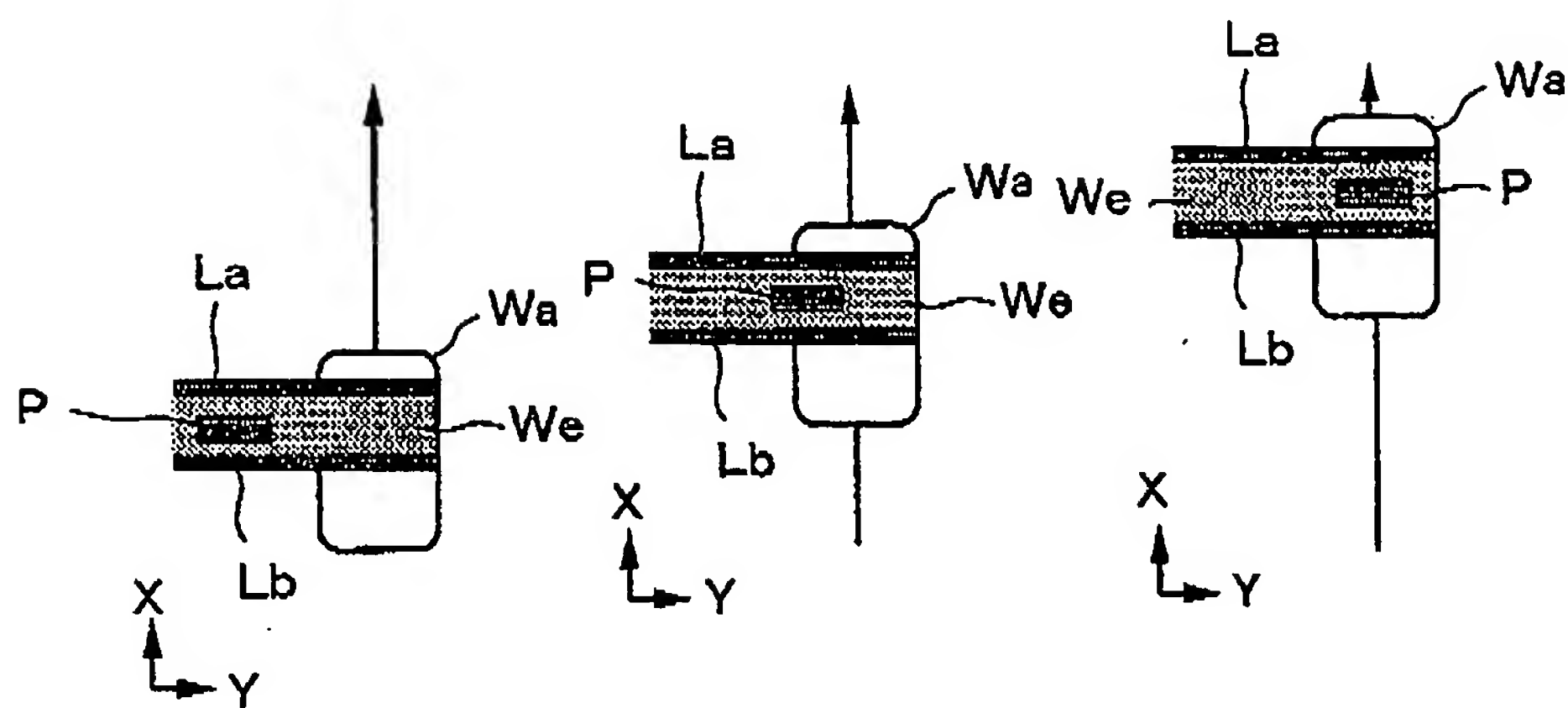
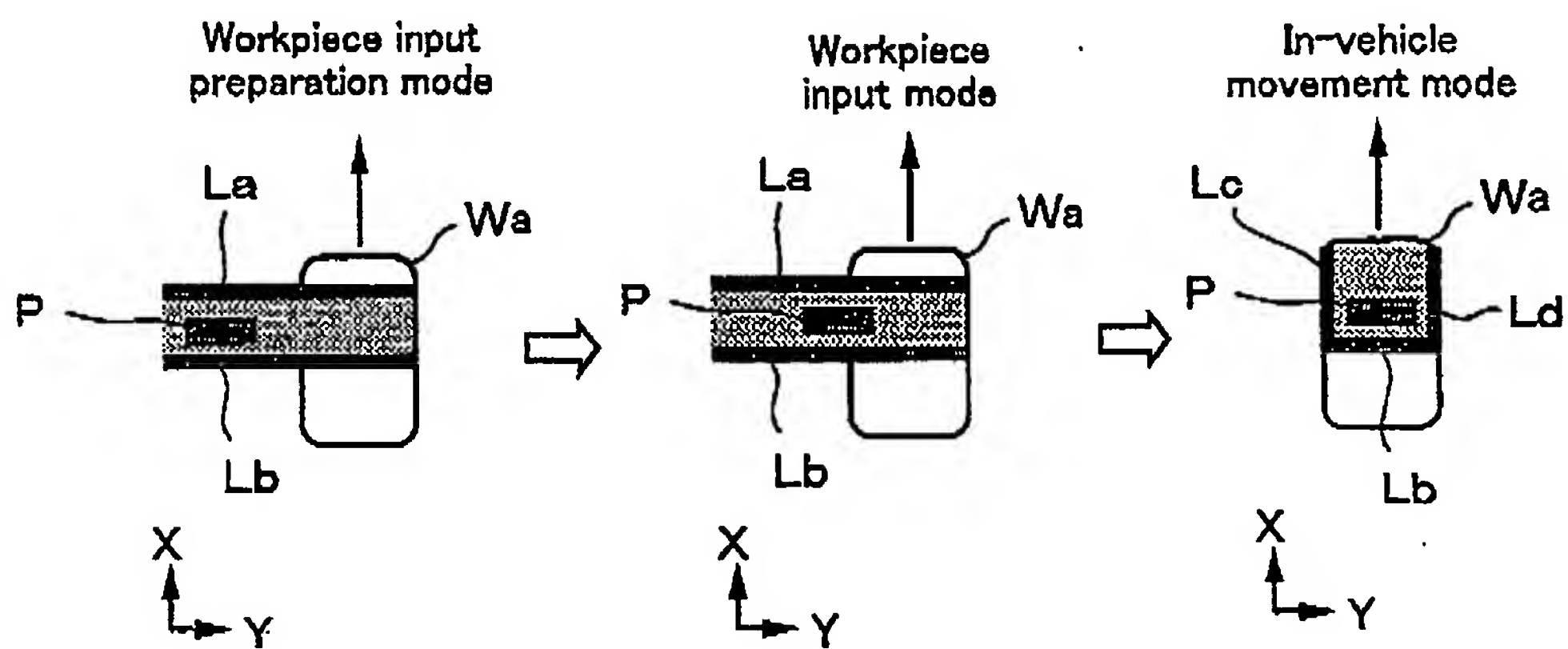
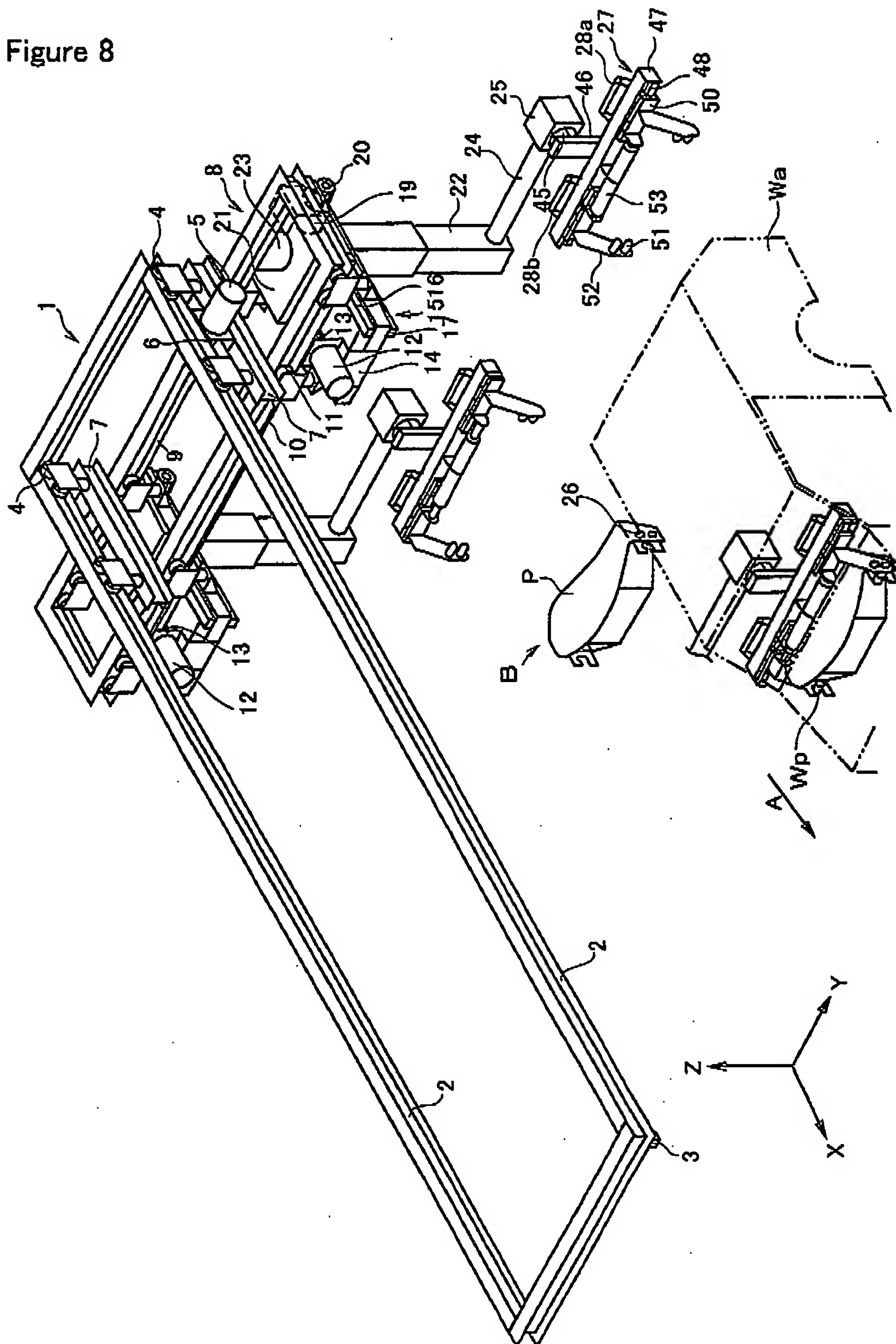


Figure 7



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Figure 8



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Figure 9

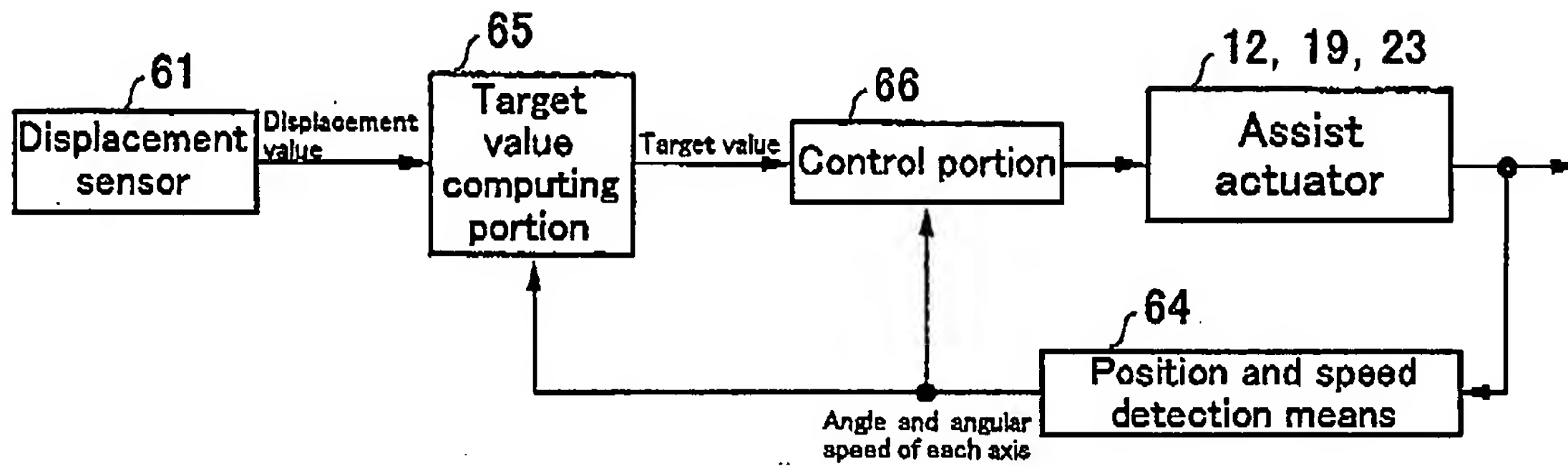
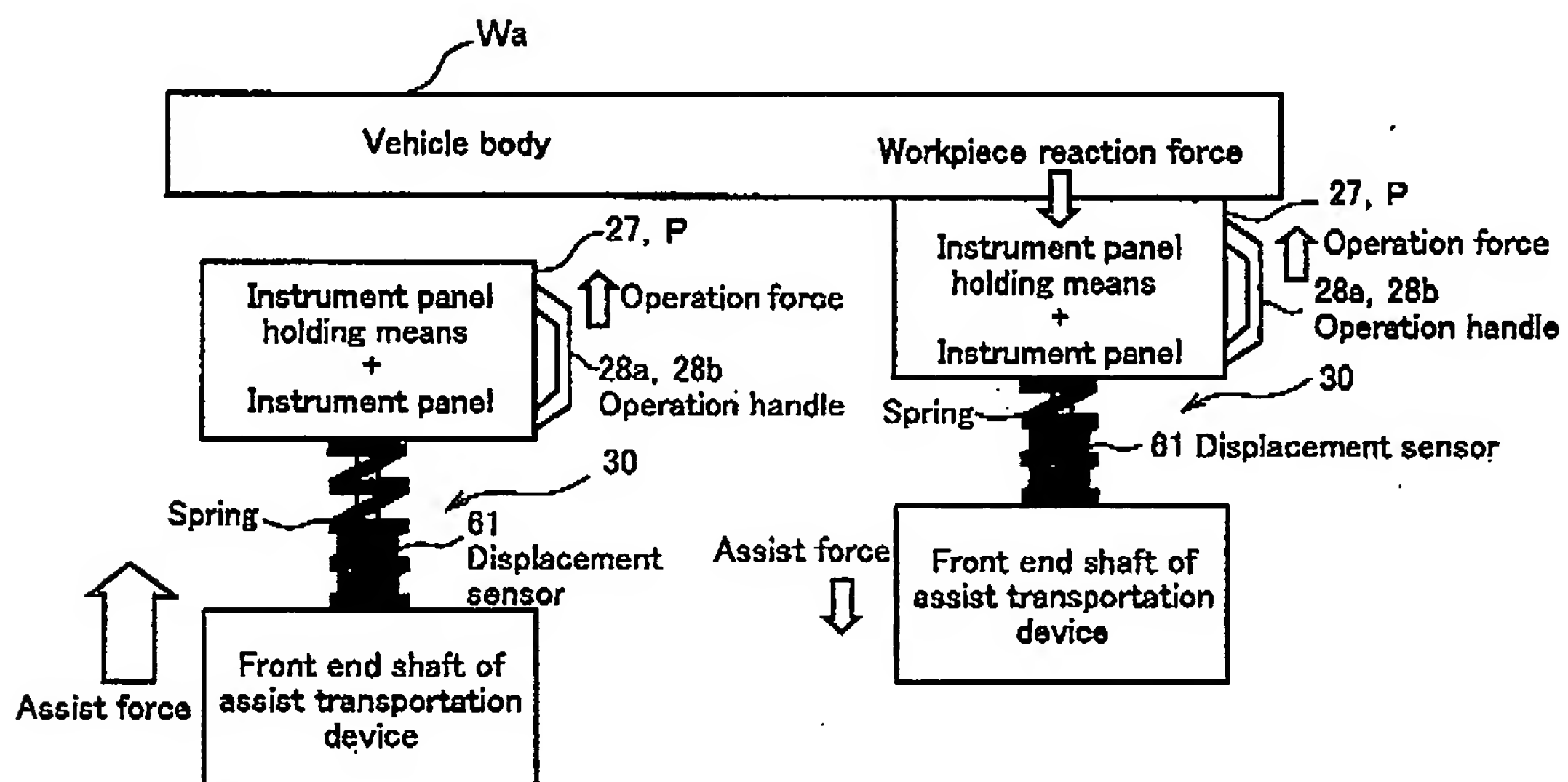
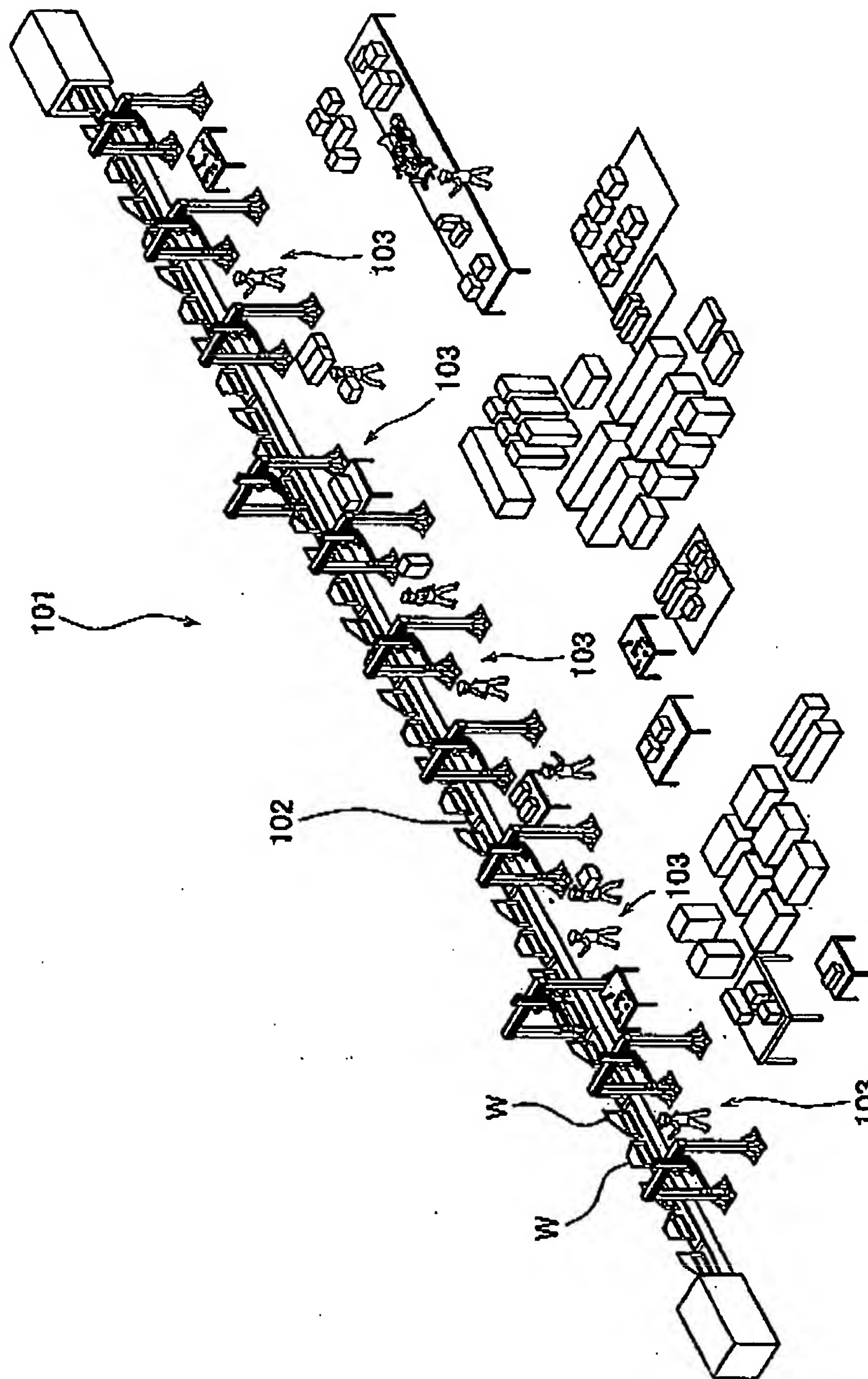


Figure 10



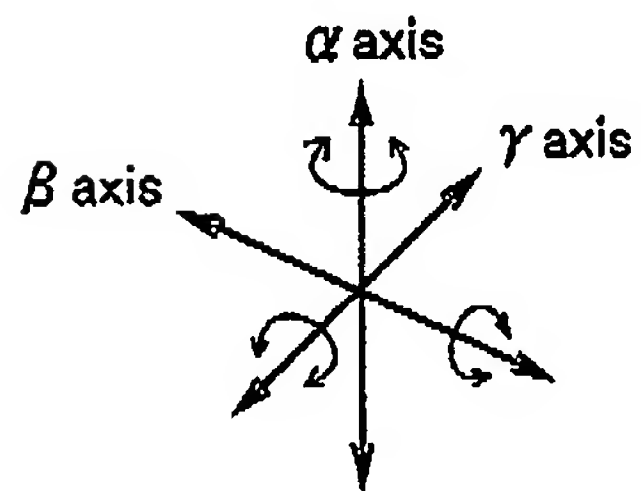
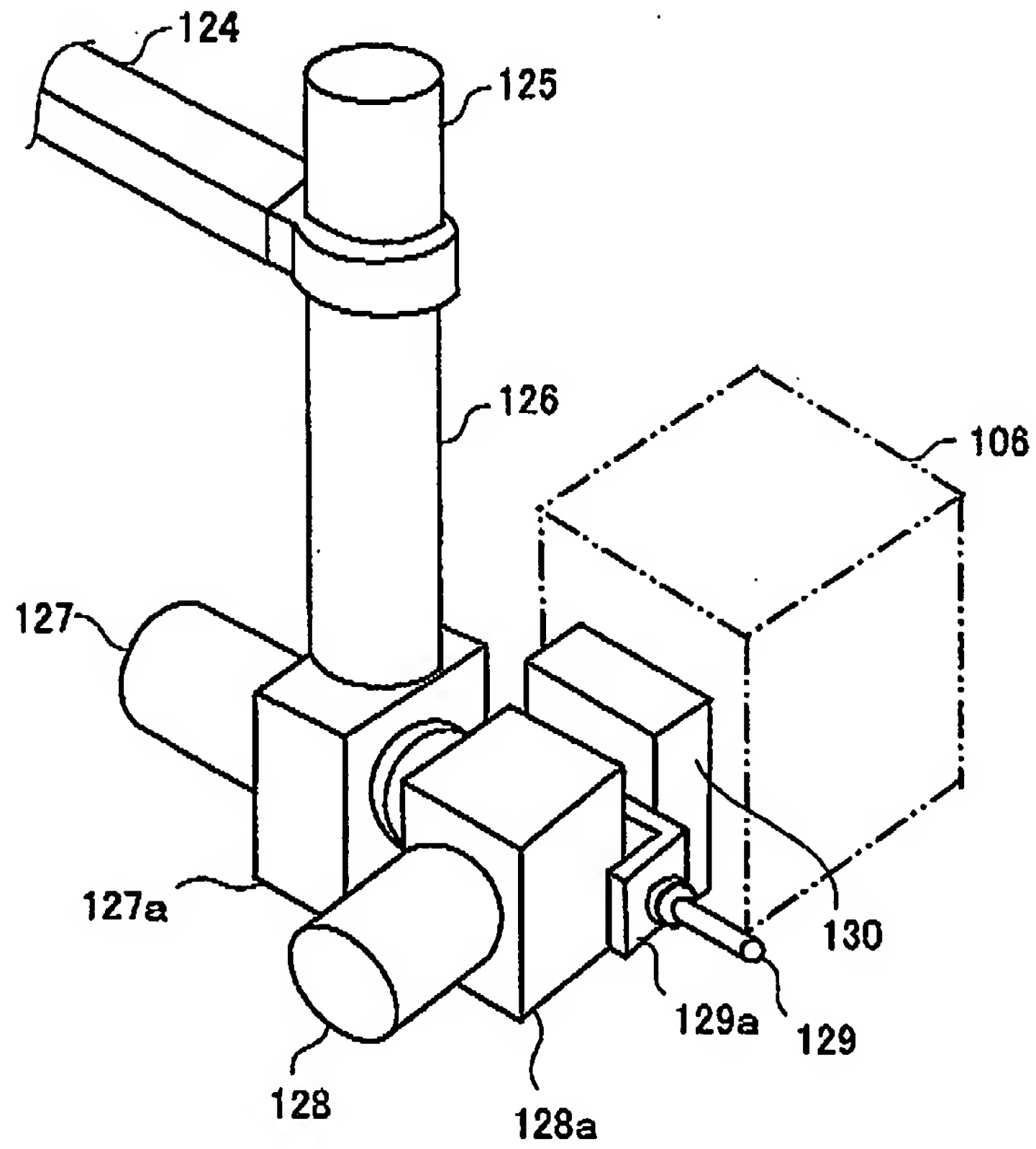
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Figure 11



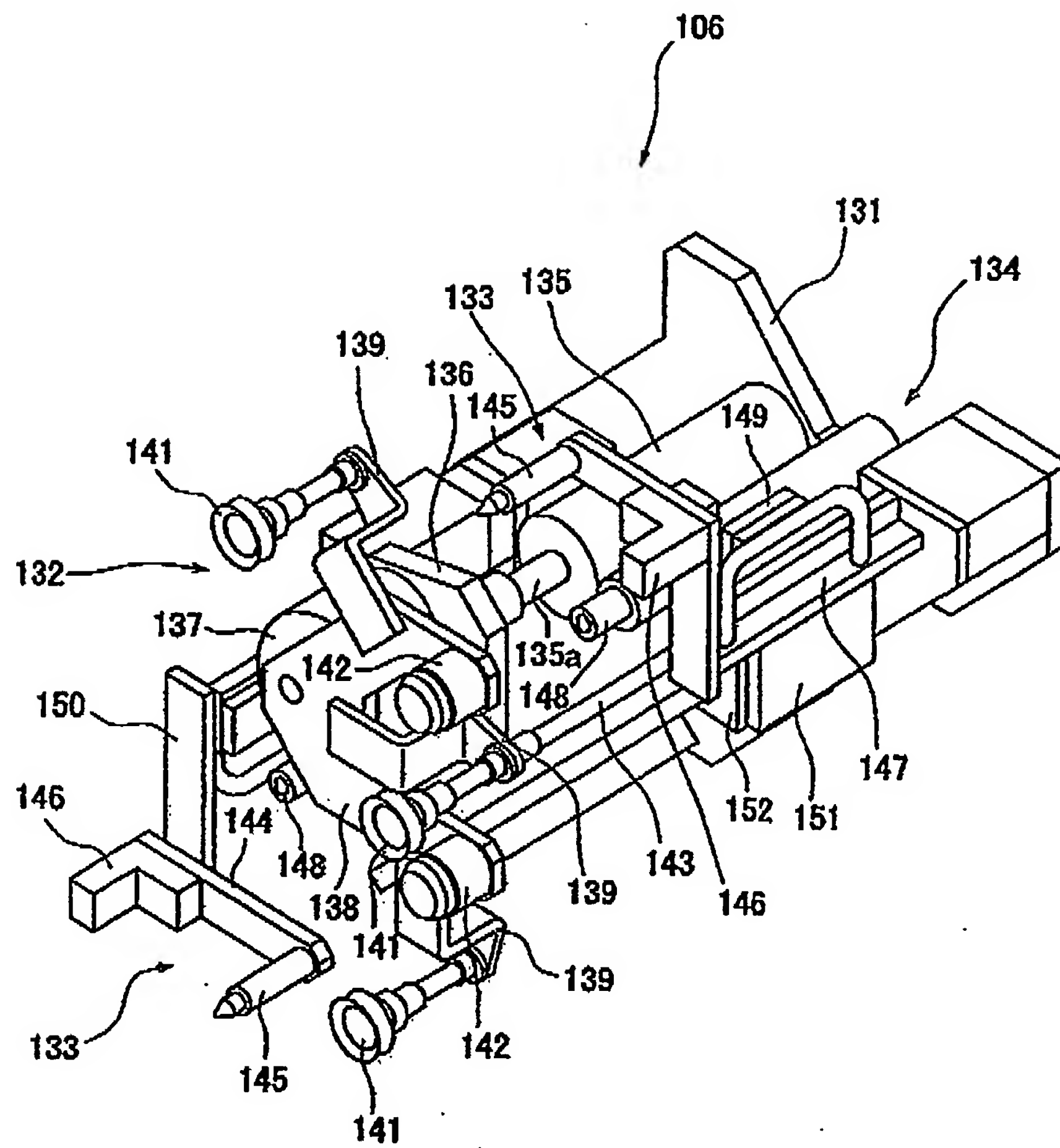
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Figure 14



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Figure 15



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Figure 16

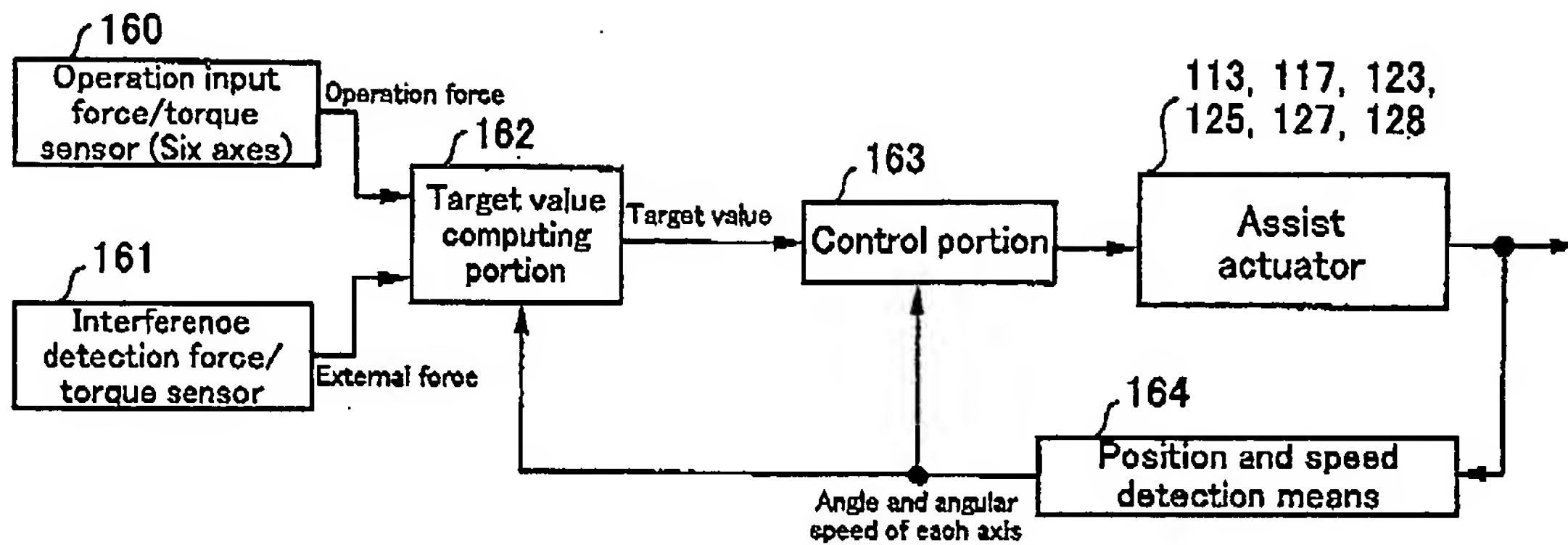
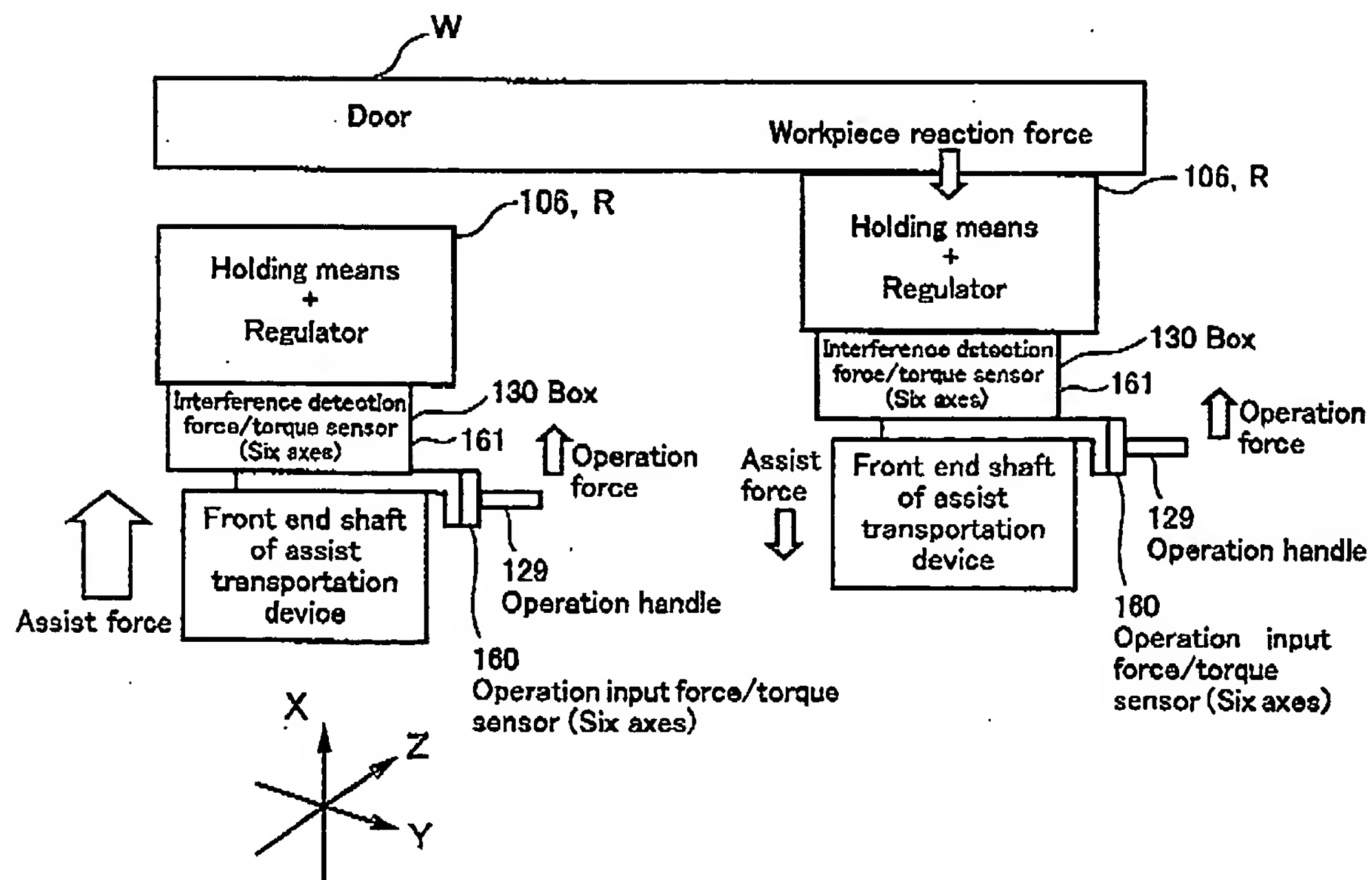


Figure 17



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Figure 18

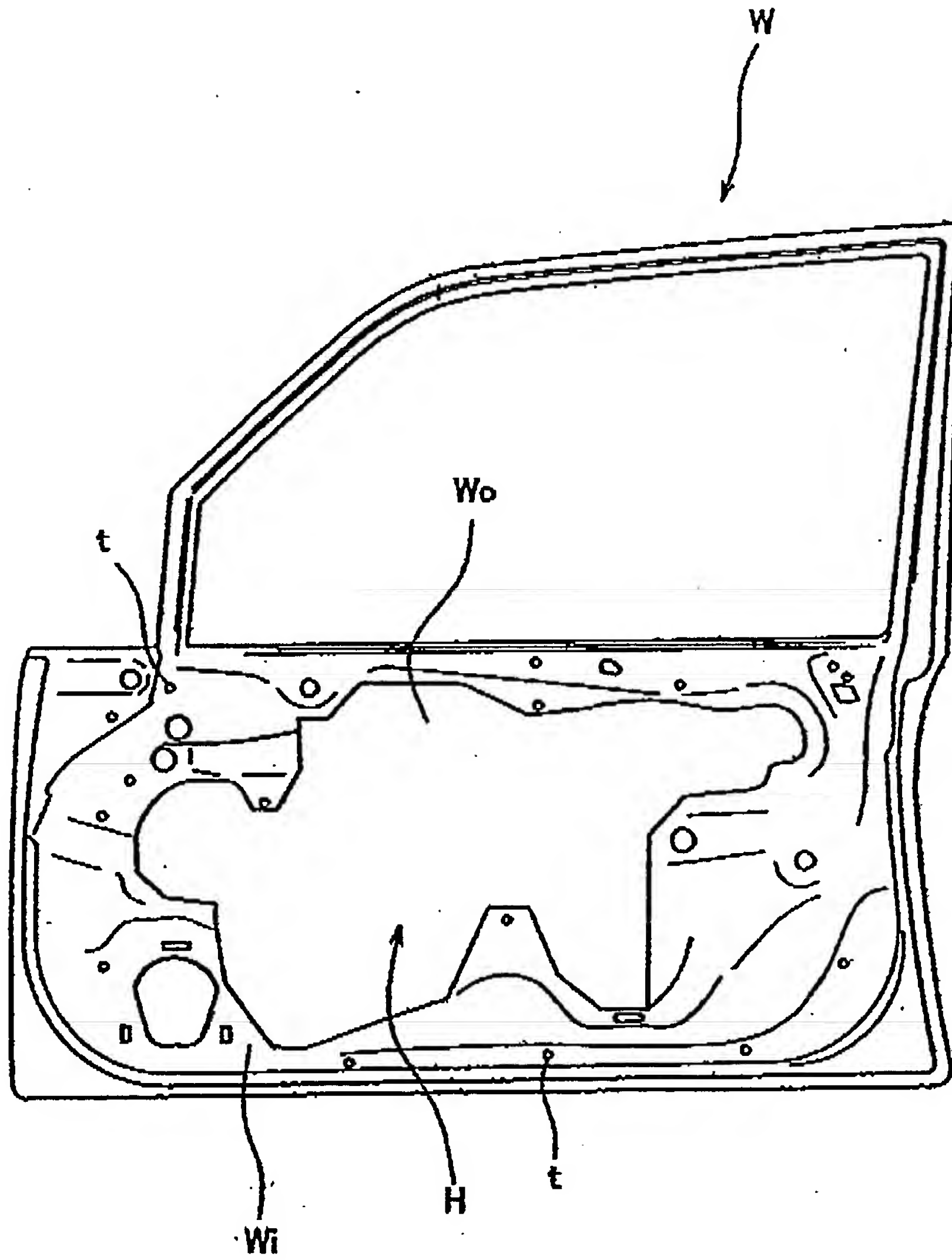
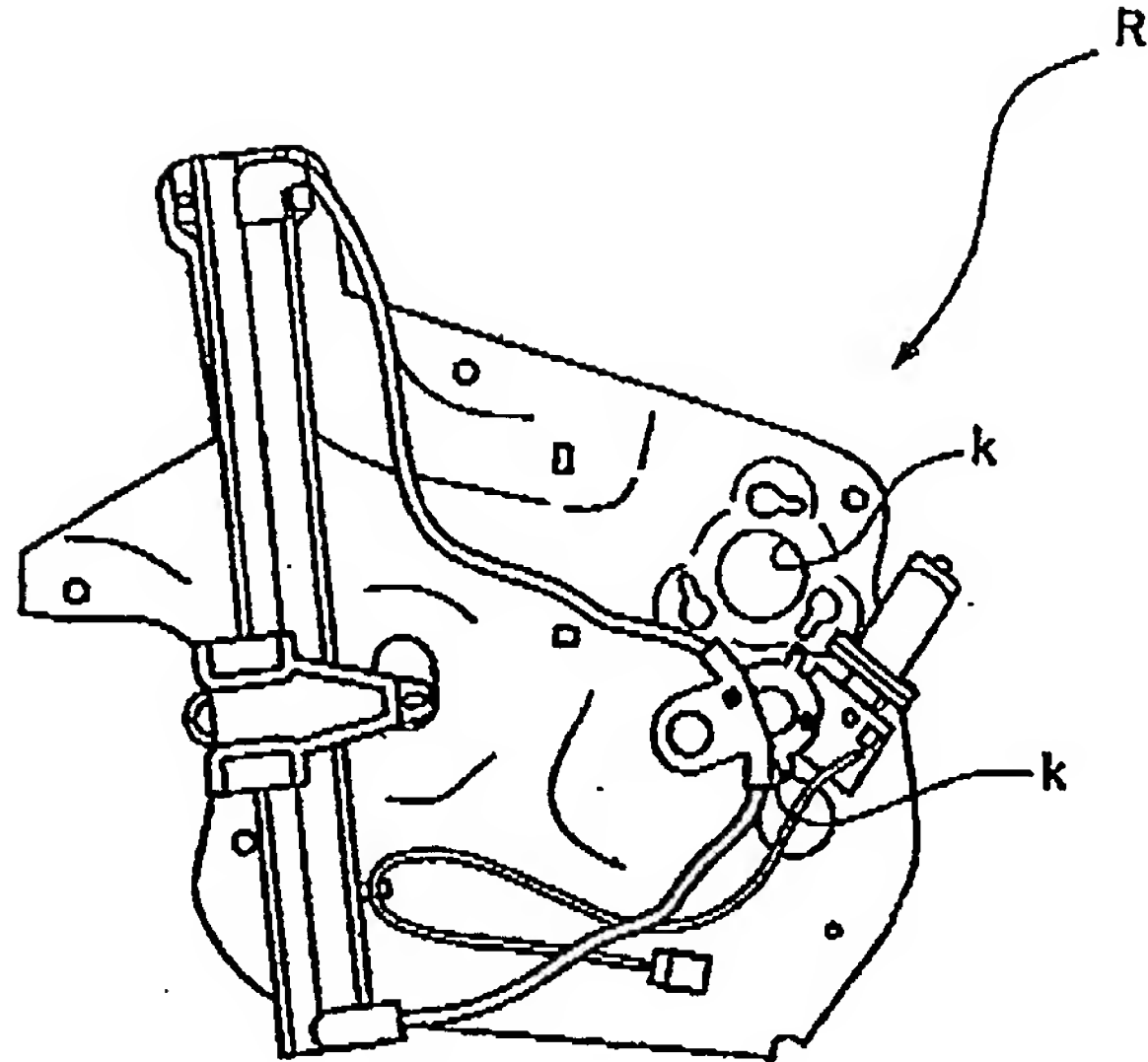
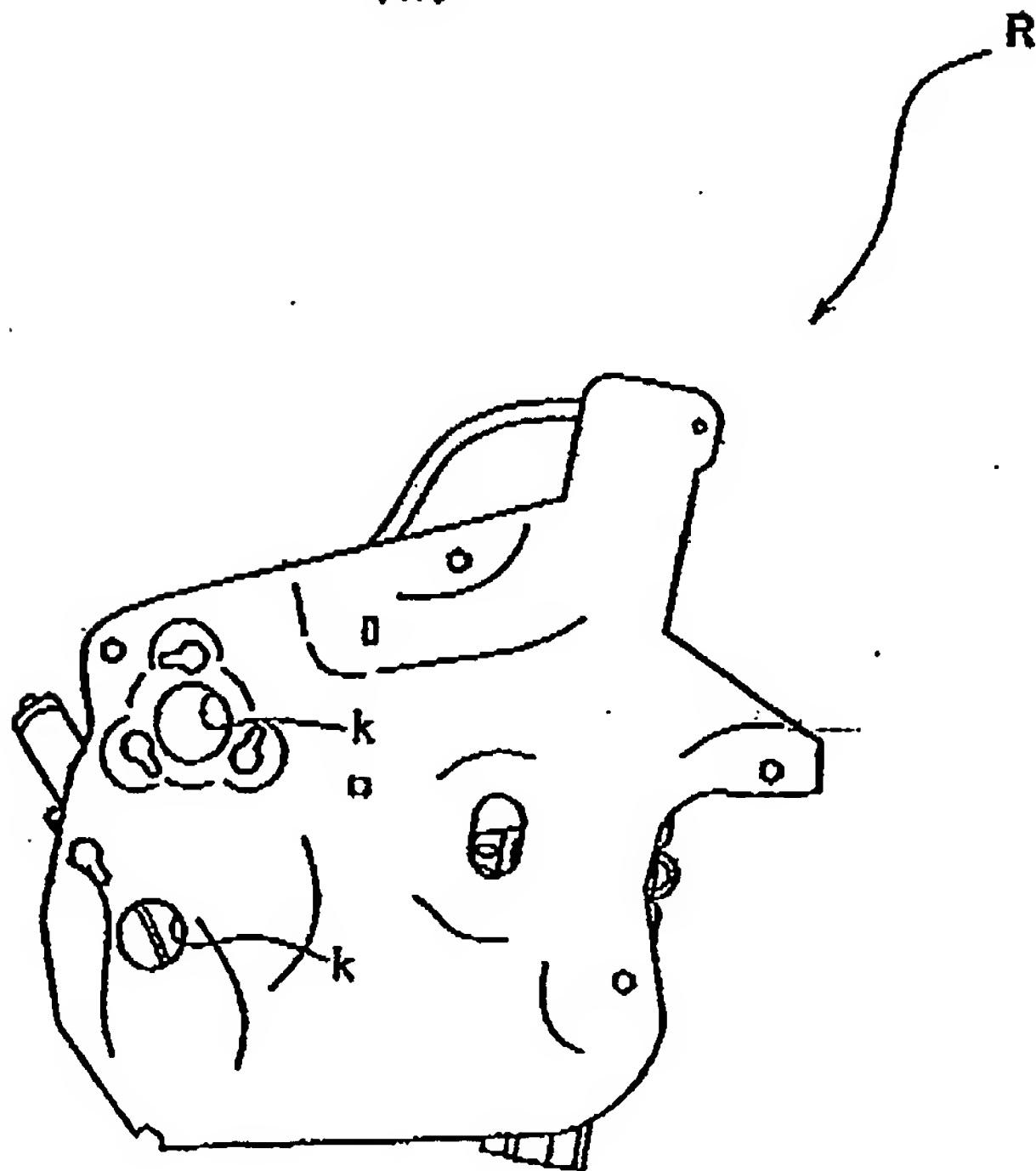


Figure 19

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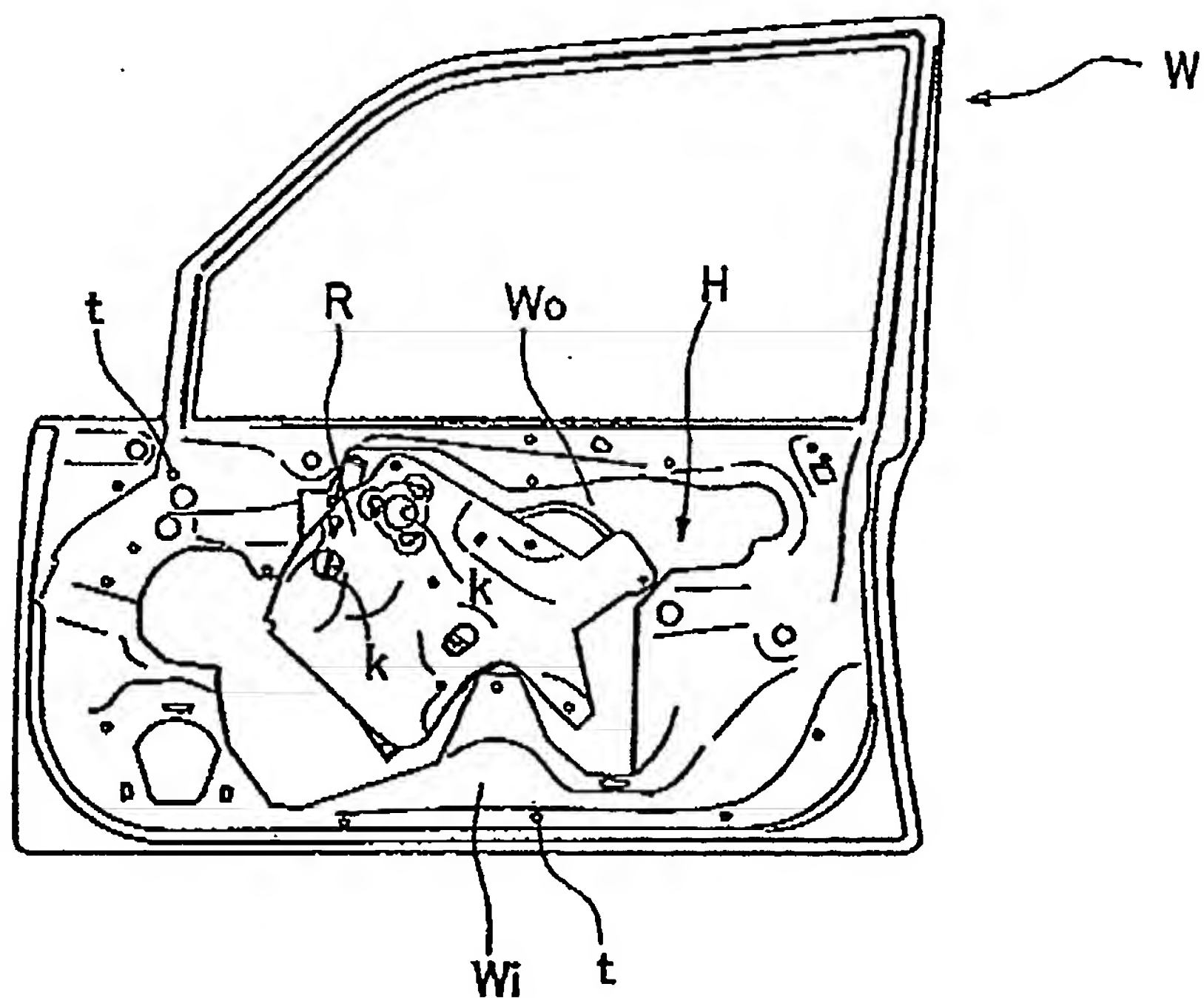
(a)



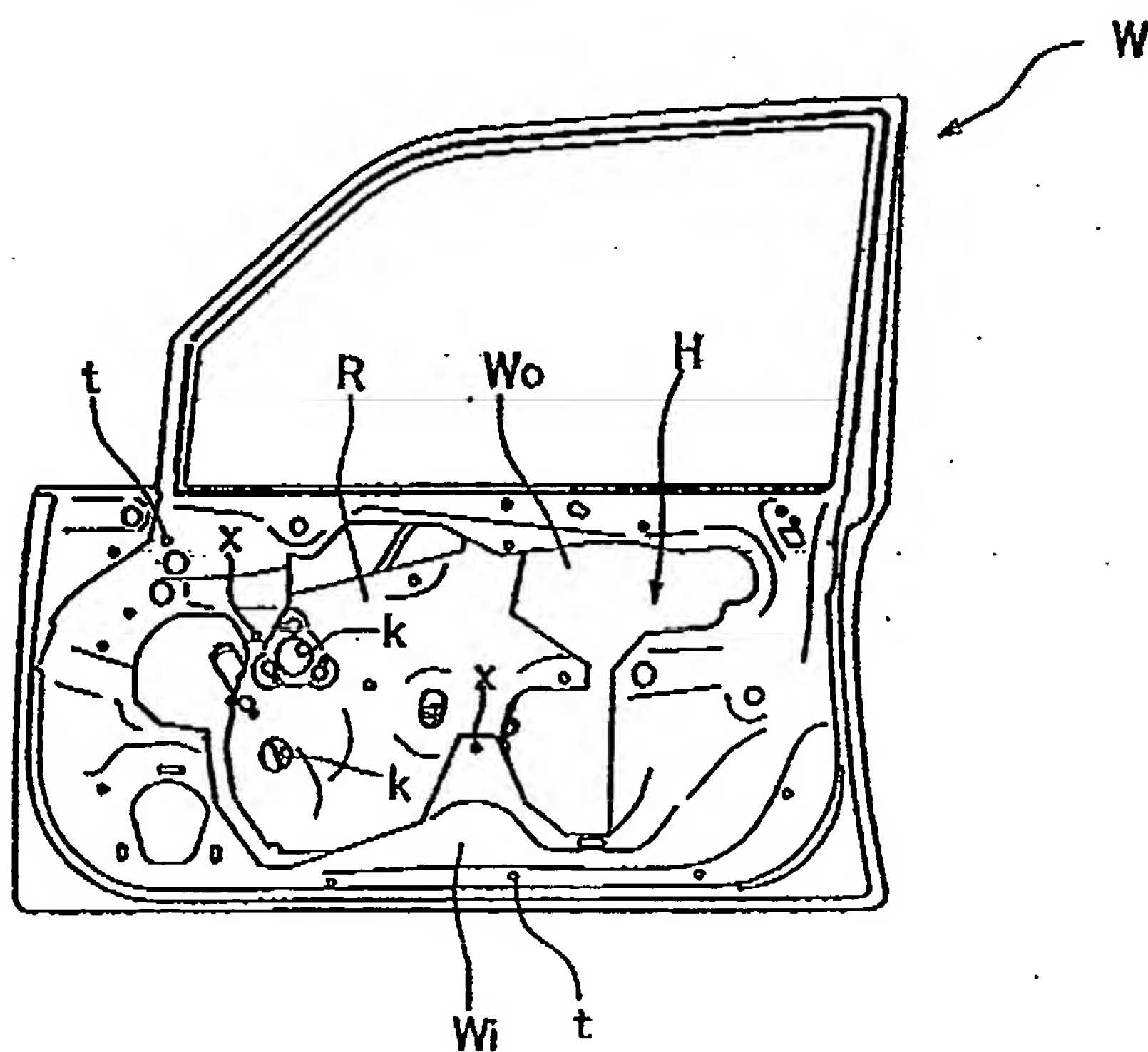
(b)

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Figure 20



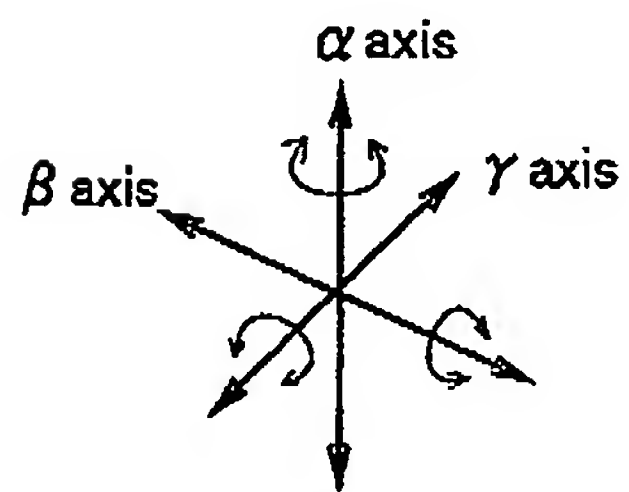
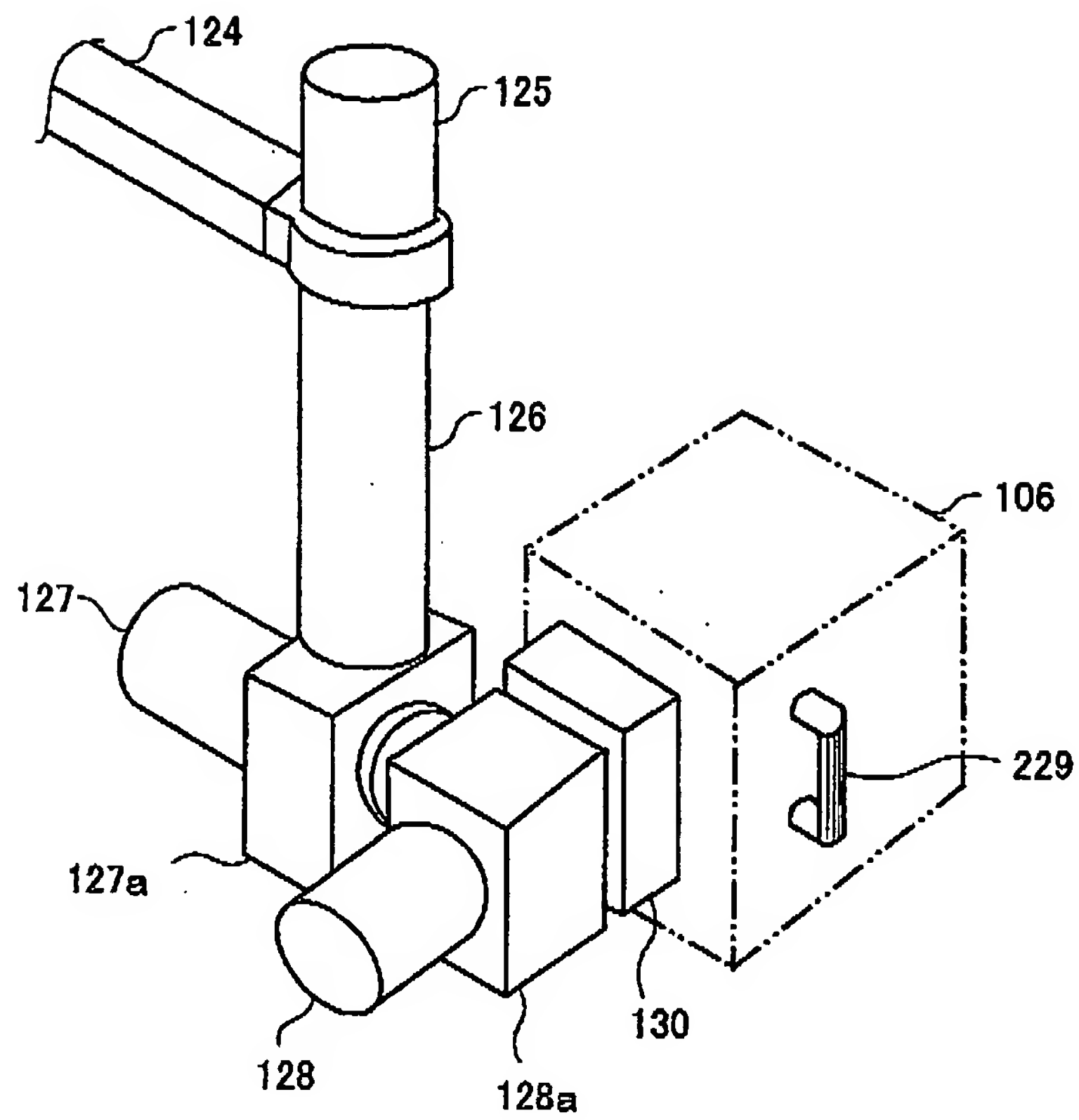
(a)



(b)

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Figure 21



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Figure 22

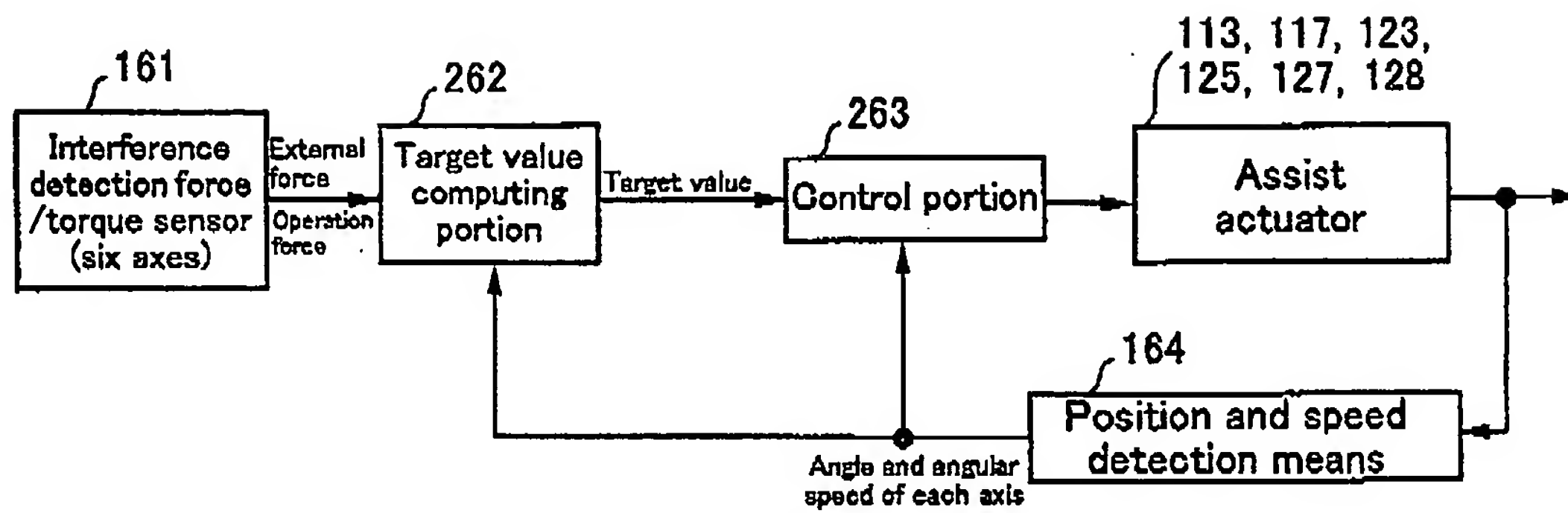
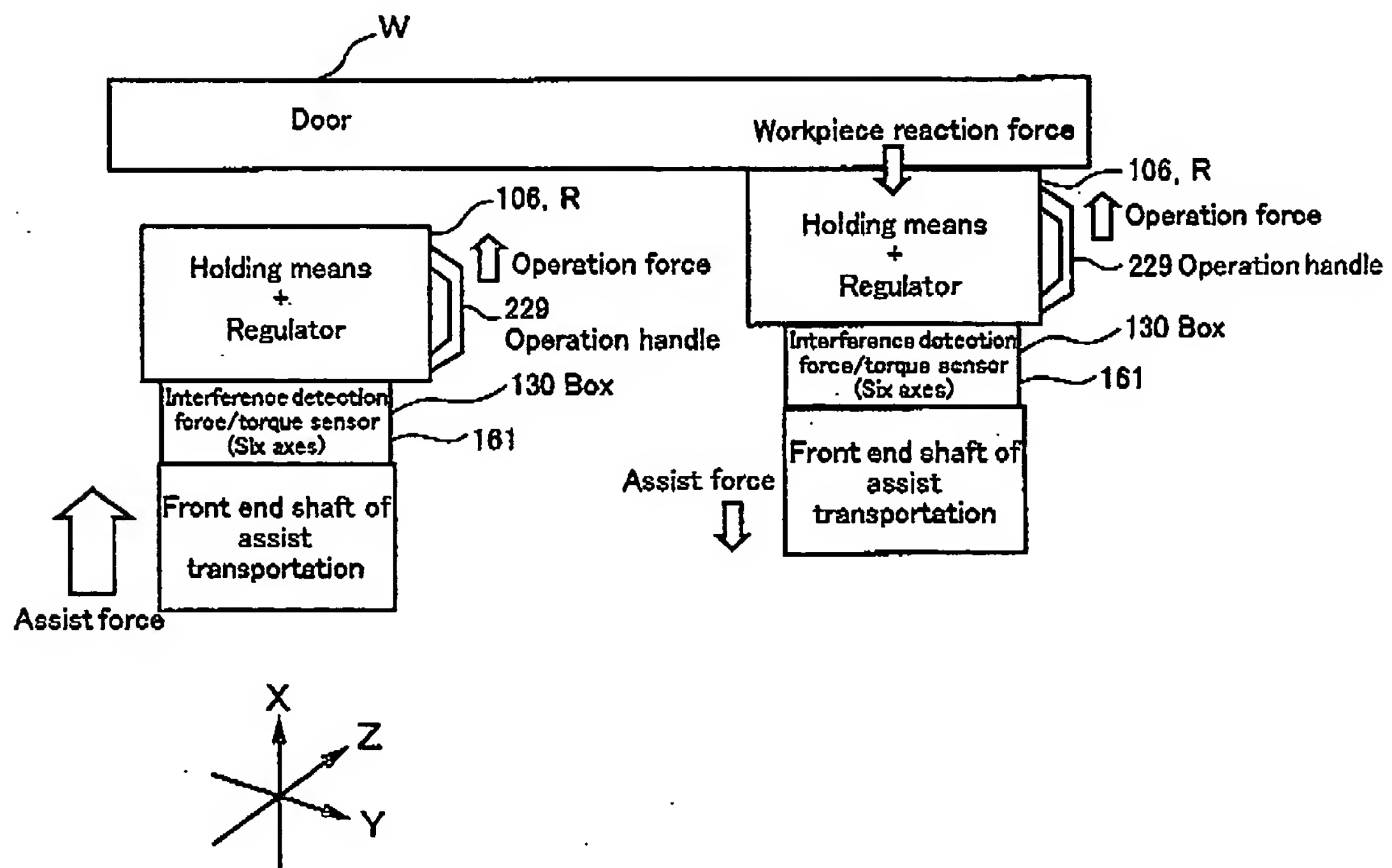
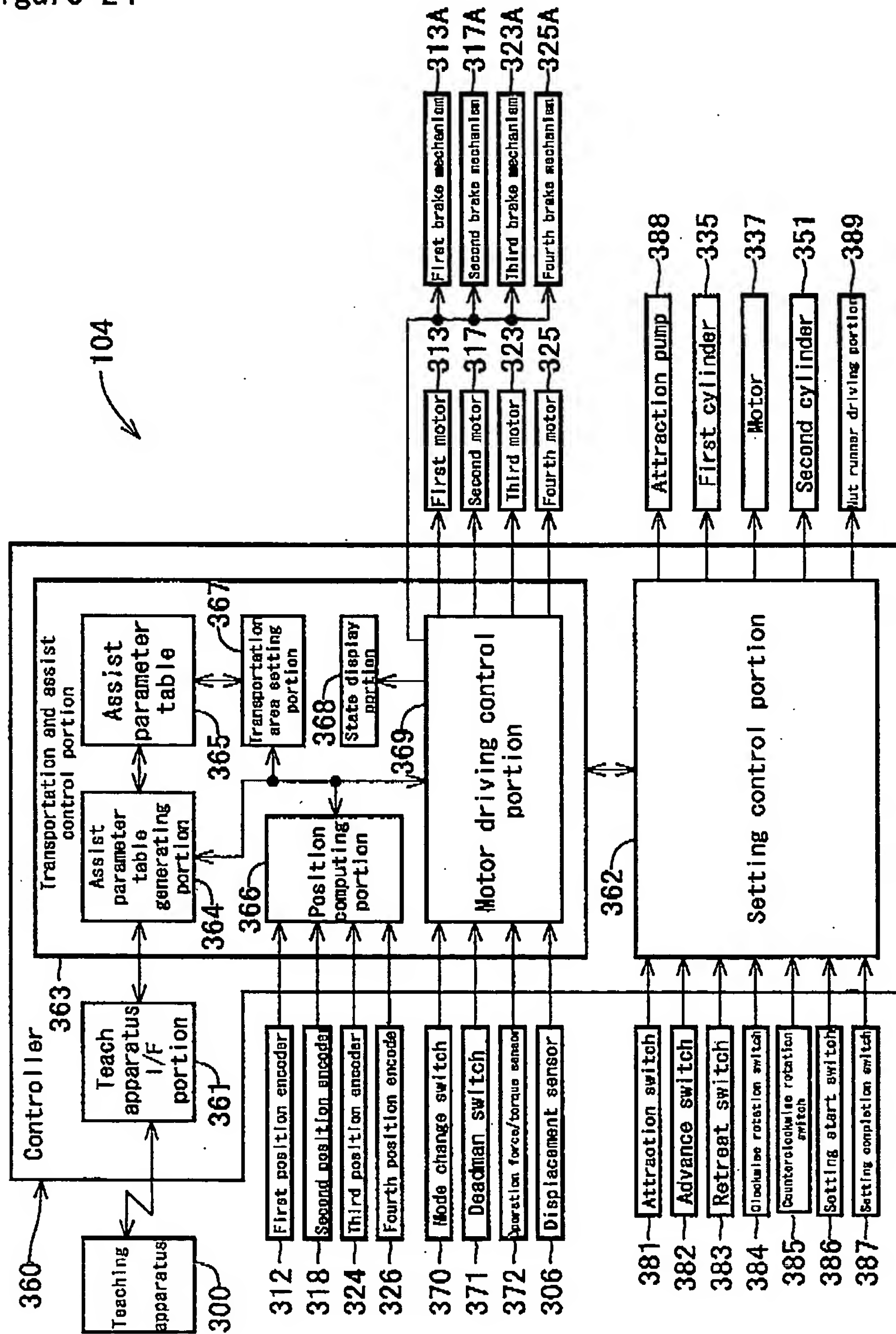


Figure 23



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Figure 24



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Figure 25

```
JOB:MAIN
0000 NOP
0001:Initialization of area and impedance
0002 ASSIST__AREA W=200 H=100 AK=10 AD=70
0003 ASSIST__IMP M=10 D=30 HK=50 HD=100

0004:Automatic operation
0005 MOVJ V=200 :P2 Automatic movement
0006 MOVJ V=100 :P3 Automatic movement

0007:Waiting for change to assist mode
0008 DOUT OT#1 ON :Announcement for prompting change
0009 WAIT AS__SW ON :Waiting for turning on assist mode switch
0010 DOUT OT#1 OFF
0011 DOUT OT#2 ON :Announcement in assist mode

0012:Operation in assist mode
0013 ASSIT__START
0014 ASIT__AREA W=50 H=50 AK=100 AD=0
0015 MOVJ V=30 :P4 Assist movement
0016 ASSIT__IMP M=40 D=160 HK=150 HD=200
0017 MOVJ V=30 :P5 Assist positioning
0018 ASSIT__END

0019:Waiting for change to automatic operation mode
0020 WAIT AS__SW OFF :Waiting for turning off assist mode switch
0021 DOUT OT#4 :Announcement for possible for automatic start

0022:Waiting for automatic start
0023 WAIT IT#1 ON :Waiting for turning on start switch

0024:Waiting for automatic start
0025 ASSIST__AREA W=200 H=100 AK=10 AD=70
0026 ASSIST__IMP M=10 D=30 HK=50 HD=100
0027 MOVJ V=200 :P6 Automatic movement
0028 MOVJ V=200 :P1 Return to origin
0029 END
```

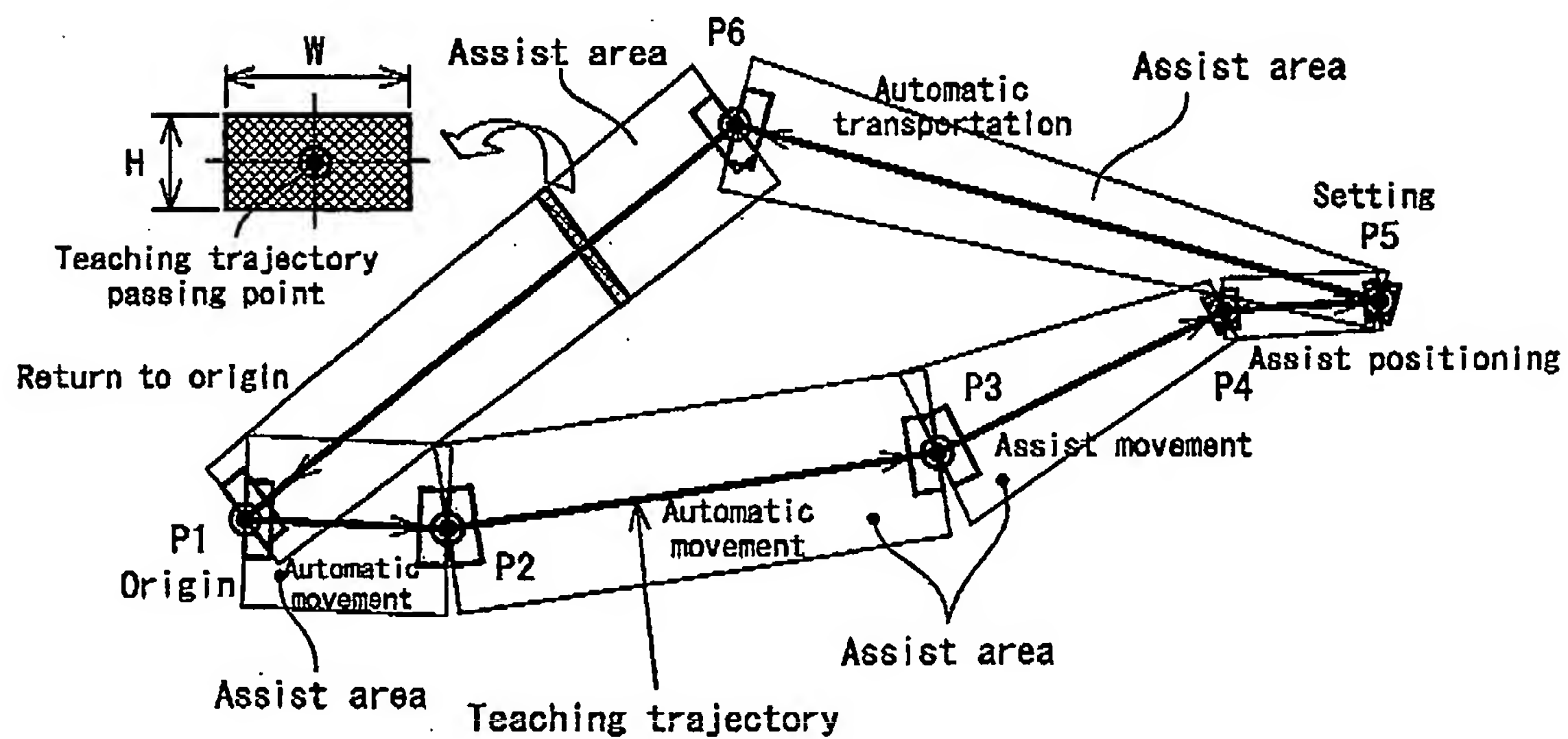
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Figure 26

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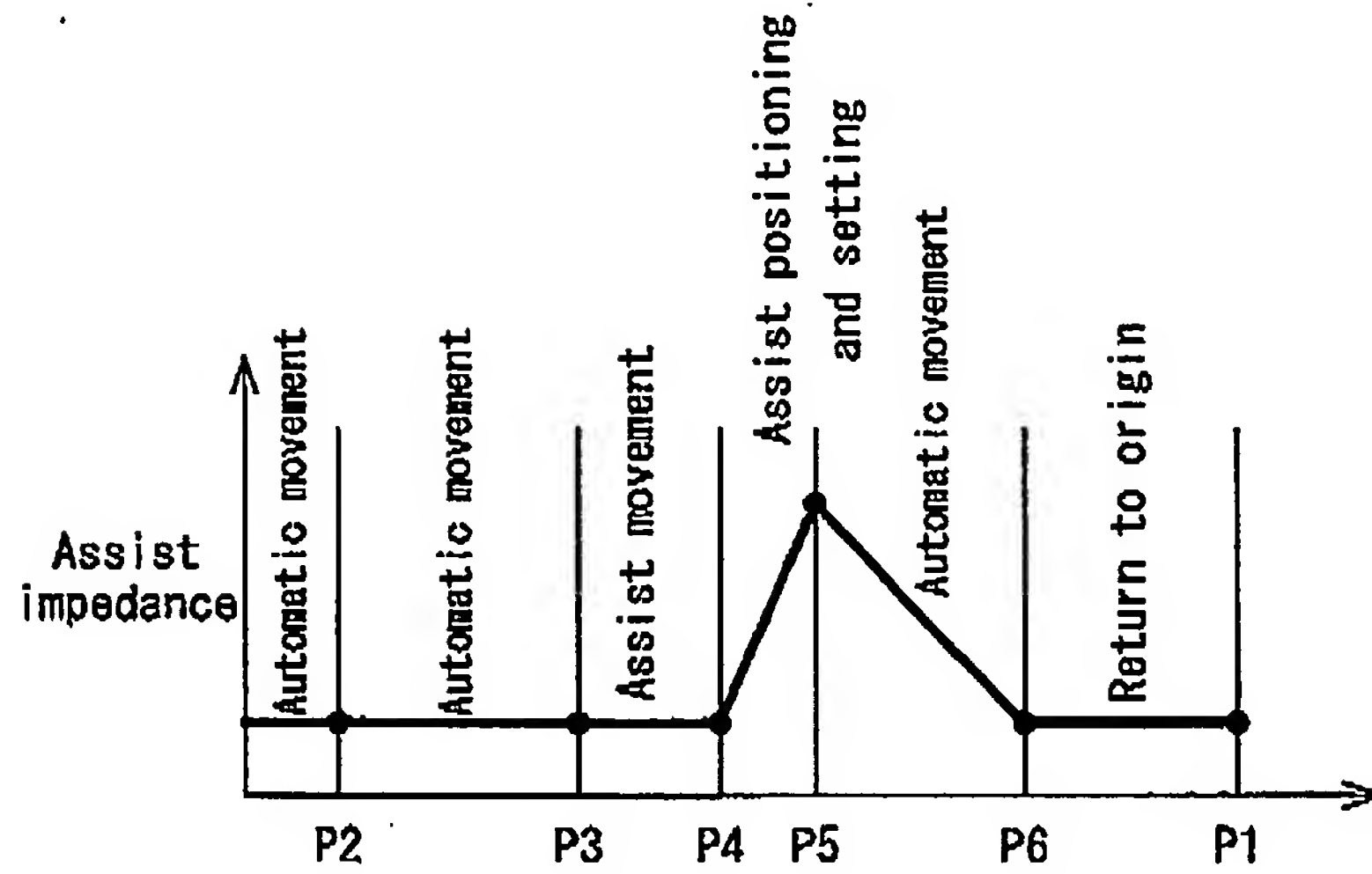
Assist parameter table								
Teaching point	W	H	AK	AD	M	D	HK	HD
P2	200	100	10	70	10	30	50	100
P3	200	100	10	70	10	30	50	100
P4	50	50	100	0	10	30	50	100
P5	50	50	100	0	40	160	150	200
P6	200	100	10	70	10	30	50	200
P1	200	100	10	70	10	30	50	100

Figure 27



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Figure 28

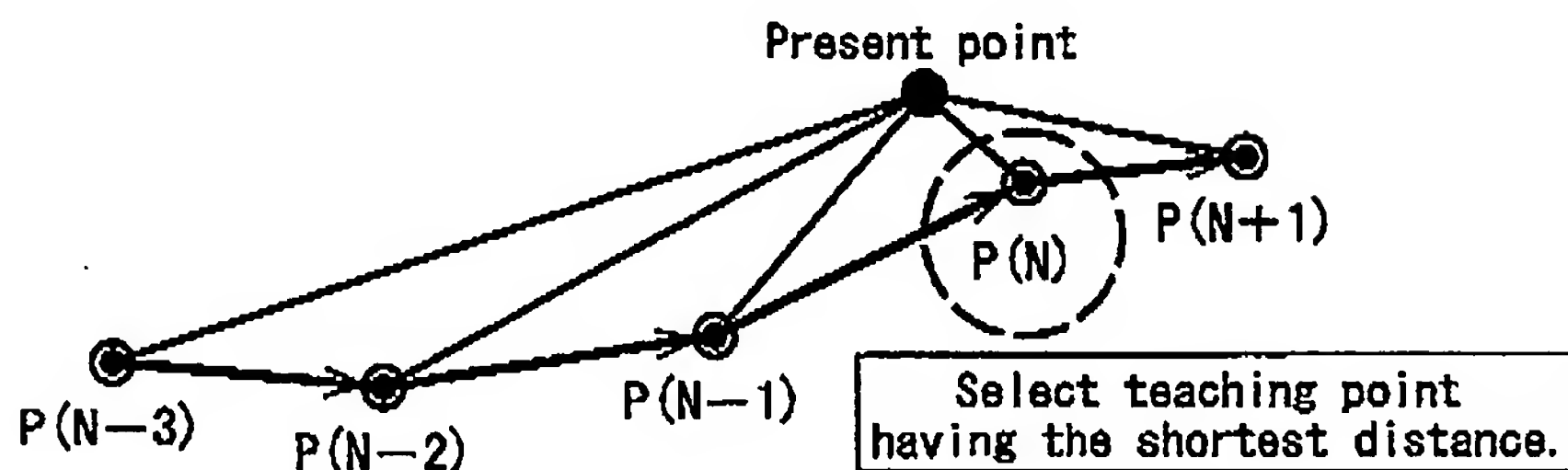


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Figure 29

(a) Step 1:

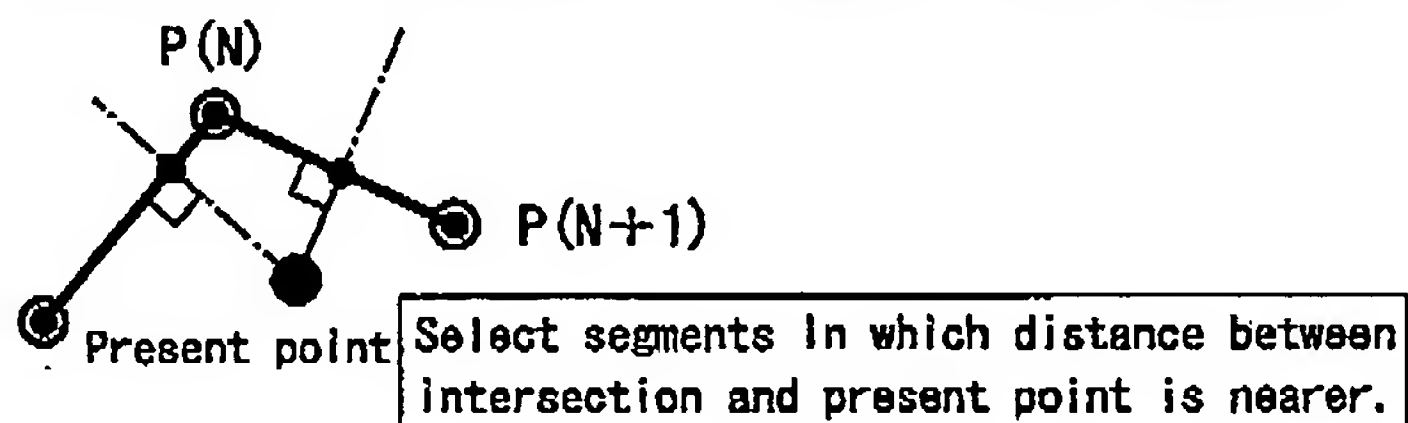
Search teaching point closest to present point.



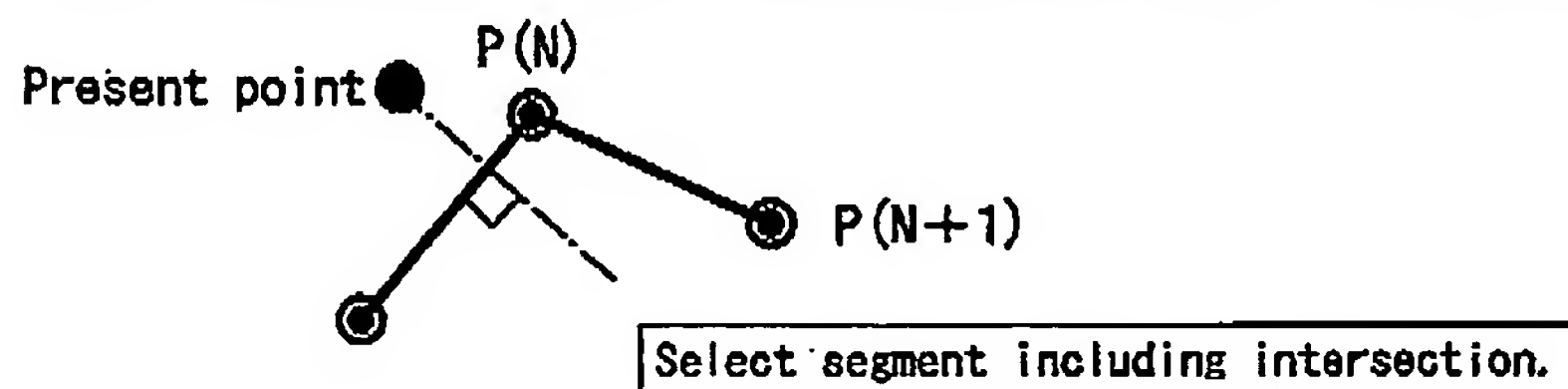
(b) Step 2:

Examine whether perpendicular intersection from present point is present in segment $P(N-1)$ to $P(N)$ and segment $P(N)$ to $P(N+1)$.

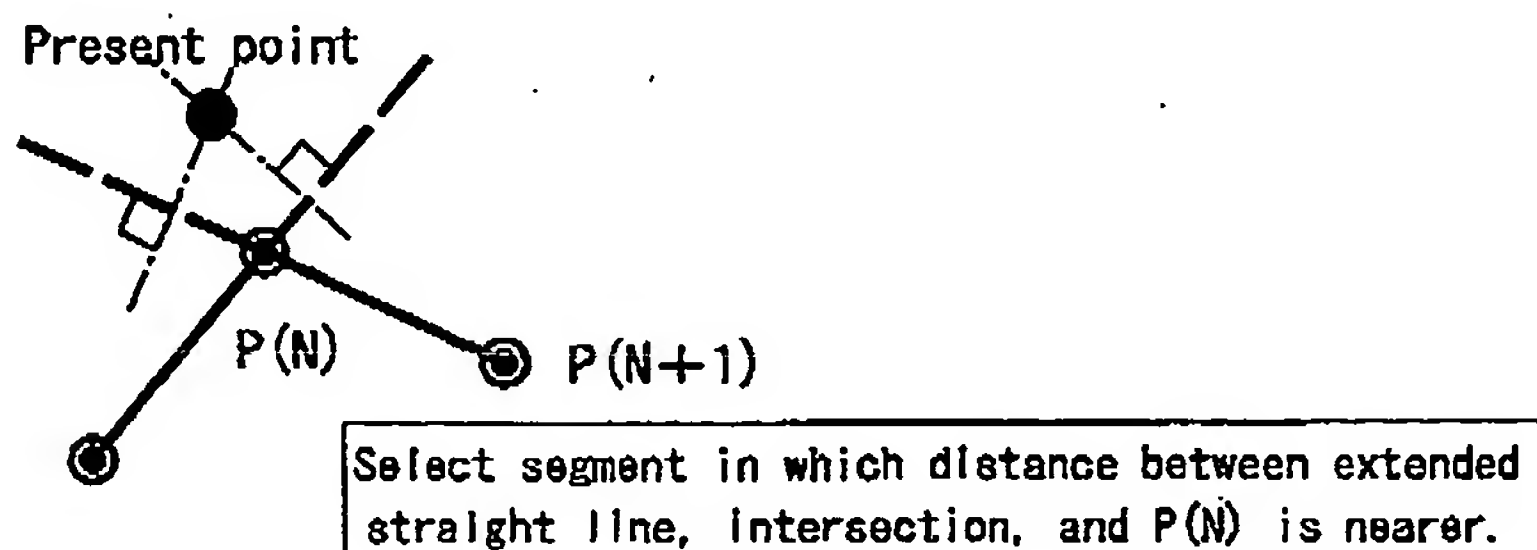
(Case 1) When perpendicular intersection is present in both segments



(Case 2) When perpendicular intersection is present in either segment



(Case 3) When perpendicular intersection is not present in both segments



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Figure 30

(c) Step 3

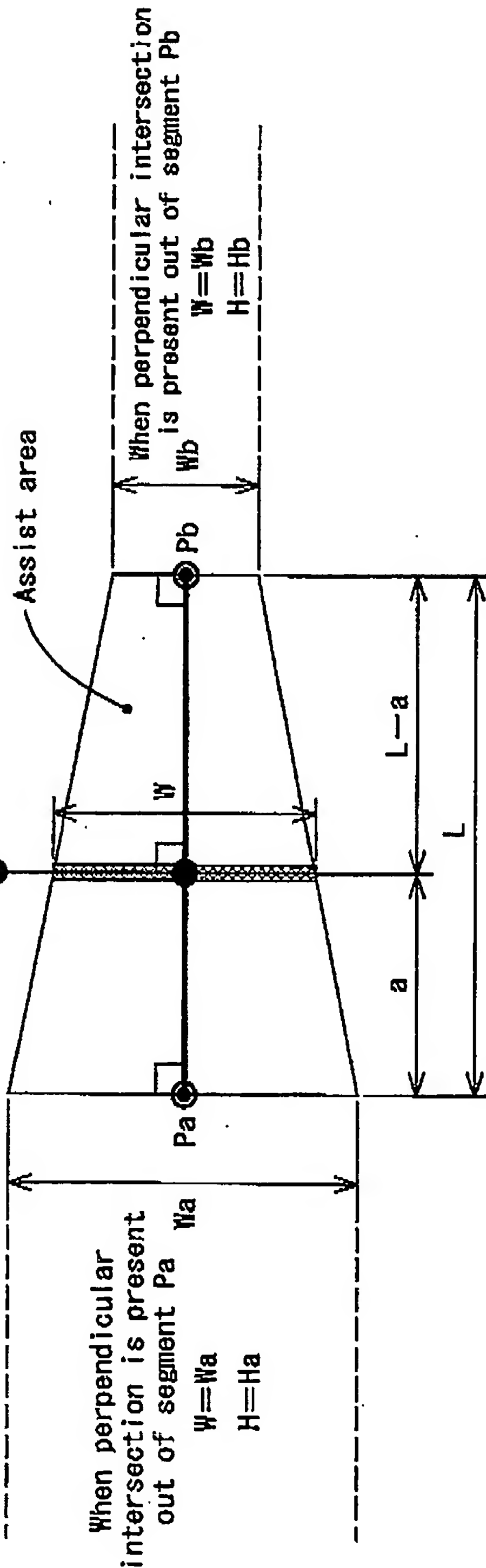
Compute assist area for selected segment.

When perpendicular intersection is present in segment Pa to Pb

$$W = Wa - (Wa - Wb) \times a \div L$$

$$H = Ha - (Ha - Hb) \times a \div L$$

Present point



Also compute invisible wall spring coefficient AK and friction coefficient AD.

When perpendicular intersection
is present out of segment Pa

$$AK = AKa$$

$$AD = ADa$$

When perpendicular intersection
is present in segment Pa to Pb

$$AK = AKa - (AKa - AKb) \times a \div L$$

$$AD = ADa - (ADa - ADb) \times a \div L$$

When perpendicular intersection
is present out of segment Pb

$$AK = AKb$$

$$AD = ADb$$

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Figure 31

(d)

Step 4

Compute virtual mass M and virtual friction coefficient D
in accordance with computation method same as the case of step 3.

When perpendicular intersection
is present out of segment Pa

$$M = M_a$$

$$D = D_a$$

When perpendicular intersection
is present in segment Pa to Pb

$$M = M_a - (M_a - M_b) \times a \div L$$

$$D = D_a - (D_a - D_b) \times a \div L$$

When perpendicular intersection
is present out of segment Pb

$$M = M_b$$

$$D = D_b$$

Also compute reaction force coefficient

HK and reaction force friction coefficient HD.

When perpendicular intersection
is present out of segment Pa

$$HK = HK_a$$

$$HD = HD_a$$

When perpendicular intersection
is present in segment Pa to Pb

$$HK = HK_a - (HK_a - HK_b) \times a \div L$$

$$HD = HD_a - (HD_a - HD_b) \times a \div L$$

When perpendicular intersection
is present out of segment Pb

$$HK = HK_b$$

$$HD = HD_b$$

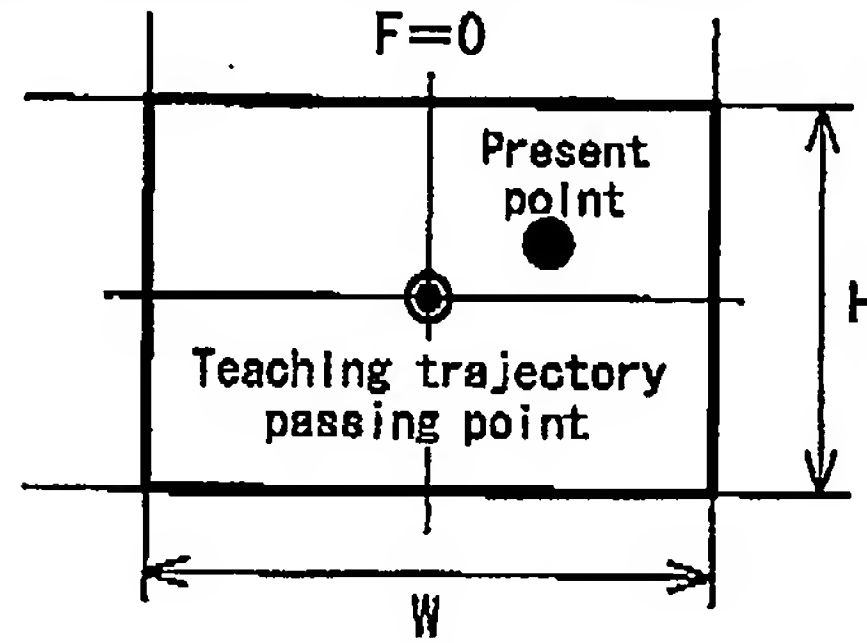
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Figure 32

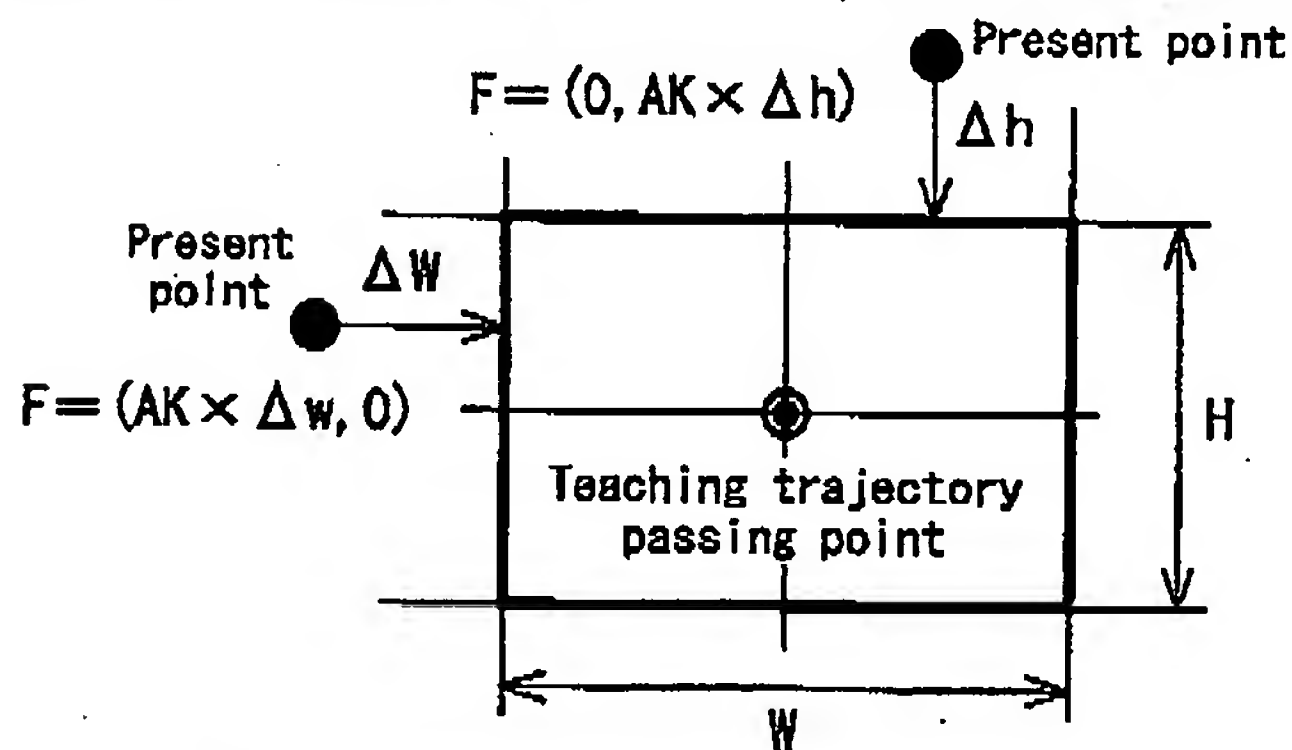
(e) Step 5-1

Computation of return force of invisible wall

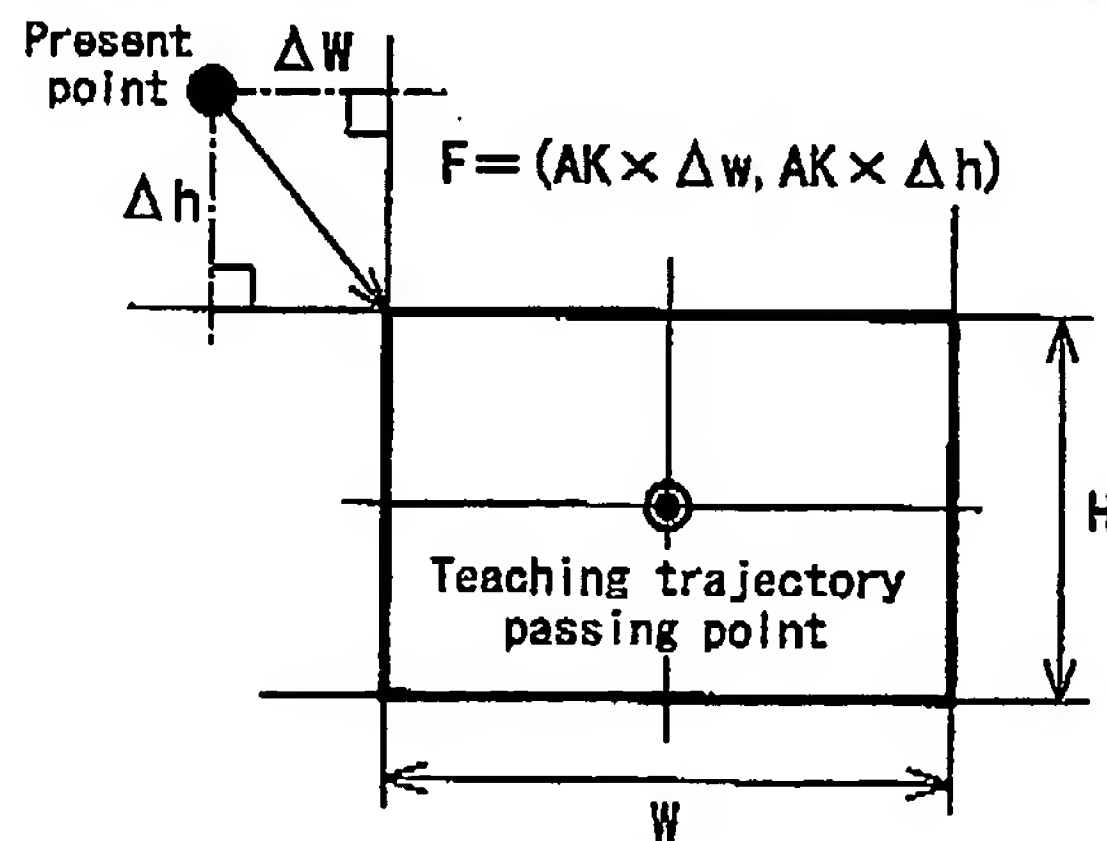
(Case 1) When present point is present in assist area



(Case 2) When present point is protruded in width or height direction



(Case 3) When present point is protruded in both width and height direction



(f) Step 5-2

Change to assist impedance

Viscosity of invisible wall is
shown by changing in-assist area: D
and out-of assist area: $D+Ad$
also for assist impedance D .